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Rio Blanco Oil Shale Company

MODULAR DEVELOPMENT PHASE
MONITORING REPORT FIVE

Volume 1 of 3

December 1978 – November 1979

Year End Report

Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
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RIO BLANCO OIL SHALE COMPANY
MODULAR DEVELOPMENT PHASE
MONITORING REPORT 5

December 1978 - November 1979

YEAR-END REPORT

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March 31, 1980

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SECTION 1
INTRODUCTION

In 1969, the U.S. Department of the Interior initiated planning for a prototype oil shale leasing program that eventually resulted in Gulf Oil Corporation and Standard Oil Company (Indiana) acquiring an oil shale lease for Tract C-a in the Piceance Creek basin of northwest Colorado in 1974. These two companies are now operating the tract under a general partnership called the Rio Blanco Oil Shale Company (RBOSC).

Since its inception in 1974, the RBOSC has been conducting extensive environmental data collection programs. Between October 1974 and September 1976, two years of baseline data were gathered. From September 1976 through August 1977, interim environmental data were collected during the period in which RBOSC had suspended tract development activities. In August 1977, RBOSC launched their Modular Development Phase (MDP) Environmental Monitoring Program. The first report of MDP environmental activities (September - November 1977) was published in February 1977. Subsequent reports were published in September 1978, March 1979, and August 1979. The current report represents RBOSC's fifth MDP Monitoring Report, and covers the period from December 1978 - November 1979.

The RBOSC MDP Environmental Monitoring Program provides air quality, meteorology, terrestrial ecology, aquatic ecology, and hydrology data. Monitoring program designs are based on analysis of baseline and interim studies data, an assessment of probable developmental impacts, and recommendations from the Area Oil Shale Office (AOSO). The monitoring conducted during this reporting period was done according to the RBOSC Modular Development Phase Environmental Monitoring Program Scope of Work dated March 30, 1979 and approved by the AOSO on April 26, 1979, with 17 Conditions of Approval. This scope of work reflects the environmental monitoring philosophy set forth in RBOSC's Detailed Development Plan (DDP).

Major responsibility for monitoring program activities rest with RBOSC Environmental Affairs Department personnel. However, several consultants were used in various capacities during this reporting period. They include: NUS Corporation (air studies data handling, water quality analyses, general consulting), Wright Water Engineers (Environmental Hydrology), Morrison-Knudsen (Operational Hydrology), MARIAH Associates (Aquatic studies), USGS (Surface water gaging station program),

GE TEMPO (Statistical support), and Dr. J. S. Warner (statistial review). Section 4.0 - Aquatic Studies was prepared by MARIAH Associates; Section 5.0 - Hydrology Studies was prepared by Wright Water Engineers. Section 5.0 includes the USGS water data. Visibility studies were carried out by Occidental Petroleum Company (Tract C-b) in a joint effort.

Data collected during MDP monitoring studies are reported semi-annually, in a mid-year and a year-end report. Monitoring Report 5, the second year-end interpretative report, presents the data collected for the six-month period, a summary of data collected for the 1979 reporting year, statistical comparisons between seasons, years, and locations, where applicable, and assessments of any impacts which may have been caused by development activities.

Objectives of the monitoring program are presented herein. Methods are presented only if they differ from the methods presented in previous RBOSC MDP Monitoring Reports, if clarification is required, or if they have not been previously reported. The "Special Studies" section discusses studies that are conducted periodically, or opportunistically as necessary, and provides a format for presenting data that might otherwise be obscured. Experimental revegetation studies data, previously provided in a separate report, are presented in Section 6.2. Volume 1 of this report contains eight sections as follows:

Section 1 - Introduction
Section 2 - Atmospheric Studies
Section 3 - Terrestrial Studies
Section 4 - Aquatic Studies
Section 5 - Hydrology Studies
Section 6 - Special Studies
Section 7 - Ecological Interactions
Section 8 - Summary

Volumes 2 and 3 contain the following data appendices:

2-1 Air Quality Data
2-2 Meteorological Data
2-5 Visibility Data
3-1 Vegetation Data
3-2 Fauna Data
4-0 Aquatic Data
5-1 Surface Water Data
5-2 Ground Water Data
6-2 Revegetation Data

SECTION 2
ATMOSPHERIC STUDIES

The Tract C-a atmospheric studies program consists of two elements -- (1) measurements of total suspended particulate matter and certain gaseous chemical compounds, and (2) measurements of selected meteorological parameters. The monitoring locations were originally established to measure the ambient air quality generally upwind and somewhat removed from the expected tract development, and at points where tract developments might have an effect on the air quality. Simultaneous meteorological measurements are being made to allow evaluations of air quality changes and for the prediction of the dispersion of emissions resulting from tract development.

Air quality and meteorological data have been obtained from monitoring instruments located on or near Tract C-a since February 1975. The first two years of data collection make up the baseline data set. Data from the baseline period were obtained at four locations around the tract. Following the baseline period, an interim data acquisition program was established to cover an interval during which the tract development lease conditions were modified and partially suspended. During the interim period (February through August 1977), a single air quality and meteorological monitoring station was operated to maintain data continuity.

The current program is part of the Modular Development Phase (MDP). The level of activity on the tract, principally construction work, has increased significantly during the MDP period. The monitoring program has been strengthened in order to measure possible effects of increased tract activity on the ambient air quality. Two of the sites that had been deactivated for the interim period were refitted with meteorological instrumentation and put back on-line during the first quarter of the MDP. In addition, one of the reactivated meteorological sites has been refitted with a complete set of air quality instrumentation (Table 2-1).

Table 2-1. Air Studies Monitoring Parameters and MDP Program Schedule, Tract C-a

Parameter	Location	Start Date	Frequency
Sulfur Dioxide	Site 1	Sept. 1977	Continuously
	Site 3	Jan. 1978	Continuously
	Site 5	July 1980	Not defined yet
Nitrogen Oxides	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Nitric Oxide	Site 1	Sept. 1977	Continuously
	Site 3	Feb. 1980	Continuously
Hydrogen Sulfide	Site 1	Nov. 1977	Continuously
	Site 3	Jan. 1978	Continuously
Carbon Monoxide	Site 1	Oct. 1977	Continuously
	Site 3	Nov. 1979	Continuously
Hydrocarbons (1)	Site 1	Sept. 1977	Continuously
Ozone	Site 1	Sept. 1977	Continuously
	Site 3	Nov. 1977	Continuously
Particulates	Sites 1, 2, 3	Dec. 1977	Every 3rd day
	Site 6 1/	Dec. 1977	Every 3rd day
Wind direction (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind direction (60m)	Site 1	Sept. 1977	Continuously
Wind speed (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Wind speed (60m)	Site 1	Sept. 1977	Continuously
Wind sigma (10m)	Site 1	Sept. 1977	Continuously
Ambient temperature (10m)	Sites 1, 2, 3	Sept. 1977	Continuously
Temperature differential (10-60m)	Site 1	Sept. 1977	Continuously
Precipitation	Sites 1, 2, 3 & other selected locations	Oct. 1977	By event
Snow depth and accumulation	Sites 1, 2, 3	Nov. 1978	By event
Solar radiation	Site 1	Sept. 1977	Continuously
Dewpoint (10m)	Site 1	July 1978	Continuously
Visibility	Visibility Shelter	Spring 1978	Semi-annually
Noise	16 locations on tract	Jan. 1978	Quarterly

1/ discontinued by agreement with AOSS

2.1 AIR QUALITY

Air quality monitoring is being conducted on and near Tract C-a to measure the concentrations of certain pollutants which may be emitted by tract operations. The ambient air quality monitoring network consists of two locations where gaseous constituents are measured (Sites 1 and 3) and three locations where particulate concentrations are measured (Sites 1, 2, and 3). These sites are illustrated on Environmental Monitoring Site Map 1--Physical (in map pocket). Sites 1 and 2 generally measure background ambient air quality, while Site 3 is located in a broad gulch that may have some air quality changes due to dispersion under downvalley flow from the main development area in the center of the tract.

All of the air quality data, with the exception of the particulate data, is collected on automatic monitoring equipment and recorded on digital computer tape and backup strip charts by a data acquisition system. The data on the digital tape are averaged into hourly values. High volume samplers are used to collect 24-hour samples of particulate data every third day at three sites.

A cooperative visibility study (with Tract C-b) has been conducted each Spring and Fall during the last two years as part of the air studies program. This year an addition has been made to the study by measuring the visual range with a telephotometer as well as with the traditional photometric technique. These data will allow comparisons to be made between the two measurement techniques.

Major improvements have been made in the air quality monitoring program during the last year. The original SO_2/H_2S analyzers (using a combination of gas chromatographic and flame photometric techniques) were the source of many maintenance problems earlier in the year. As a result, they have been replaced by state-of-the-art pulsed fluorescent SO_2 and H_2S analyzers at each site. The SO_2 analyzers have EPA certification as SO_2 equivalent methods. In addition, CO and NO/NO_x analyzers have been refurbished and installed at Site 3.

Air quality data taken during the eighth and ninth quarters of the MDP program are presented in Appendices 2-1.1 (gaseous constituents) and 2-1.2 (total suspended particulates).

As part of the year-end report, an extensive analysis has been carried out on the data obtained during the most recent four quarters of the MDP program (December 1978-November 1979, hereafter referred to as the current year). Comparisons have been made with the results from the baseline period (February 1975-January 1977), obtained from the Final Environmental Baseline Report (RBOSP 1977), and with the previous year (December 1977 - November 1978) of the MDP period (RBOSC MDP Monitoring Report 3).

A real concern in the evaluation of any set of data is the significance of that data. This is particularly true of air quality data gathered in a pristine environment, such as found at Tract C-a. Concentrations of several gaseous constituents are at or below the minimum measurement capability of air quality monitoring instruments much of the time. Before any meaningful statistical analyses can be applied to these data sets, they must be carefully reviewed to determine if analyses are appropriate.

A quantitative measure has therefore been developed to use as a conservative minimum level, below which there is essentially no probability that the values represent real and valid data. This level, called the threshold of detection, is defined as twice the noise level of the instrument. The threshold of detection can thus be used to determine if there is a sufficient number of valid data points to warrant further statistical analyses.

It should be emphasized that the threshold of detection is a conservative measure to use in determining data validity. That is, arbitrarily defining the threshold of detection as twice the noise level of the instrument is designed to take into account the errors or uncertainties which develop when measurements are taken at the minimum limit of any monitoring system. These uncertainties are extremely difficult to quantify, but may result in the true level of significance of the data being above the threshold of detection. Consequently, the threshold of detection used here is designed to be a conservative measure of data validity. That is, some data that is not significant (within the noise of the measurement system) may be retained, but no valid data will be arbitrarily discarded (due to tests of significance set too high).

The ultimate goal is to provide confidence limits around the data collected by each instrument, which will serve as more realistic criteria with which to judge the validity of the data. However, given the number of uncertainties in the measurement system, this is not an easy task. It will be aided by more experience with each instrument and by the development of our data management system.

As discussed above, the threshold of detection is defined as twice the noise level of the instrument (supplied by the manufacturers). Values for each instrument are given in Table 2-2. These detection limits can be used as a guide to determine how much of the data can be considered statistically valid. The significance of the data for each parameter will be discussed separately in the appropriate section below.

A. Sulfur Dioxide

1. Objectives

The objective of monitoring for sulfur dioxide is to establish the ambient air concentration prior to and during tract development. The existing sulfur dioxide levels and their associated environmental effects can be compared to future environmental changes that may be related to any increase in the concentration of sulfur dioxide.

2. Methods

The methods followed for collection of sulfur dioxide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein. New SO_2 monitors were installed toward the end of the current year (during July at Site 1 and during October at Site 3), because of instrument outages and maintenance problems with the original Bendix Model 8700X analyzers. The new instruments have a lower threshold of detection (Table 2-2) than the original instruments (0.005 ppm). This will be reflected in the minimum values given in the next monitoring report.

Table 2-2. Air Quality Instrumentation used at Tract C-a, with the Lower Detectable Limit for each Monitor

Variable (ppm)	Manufacturer	Model	Technique	Lower Detectable Limit (ppm)
SO_2	Thermo Electron Corporation	43	Pulsed Fluorescence	0.002
H_2S	Thermo Electron Corporation	45	Pulsed Fluorescence	0.002
NO/NO_x	Bendix	8101-B	Chemiluminescence	0.005
Photochemical Oxidant (O_3)	Bendix	8002	Chemiluminescence	0.001
CO	Bendix	8501-5CA	Nondispersive infrared detection	0.5

3. Results and Discussion

Table 2-3 provides mean, maximum, and minimum concentrations of air quality variables monitored at Tract C-a during the current year. The table shows that maximum concentrations of SO_2 were 0.03 ppm at Site 1 and 0.09 ppm at Site 3, and mean concentrations were 0.01 ppm at both sites. Thus, almost all of the SO_2 concentrations monitored during the current year were at or below the threshold of detection for the instruments. This fact is not surprising, since there have been no major emissions of SO_2 to date at or near the tract.

Comparison of the current year's data (Table 2-3) with data from last year (December 1977-November 1978, Table 2-4) and the baseline period (February 1975-January 1977, Table 2-5) show similar values. The highest concentrations of SO_2 found during the four years of data summarized in this report is 0.11 ppm, which occurred during the baseline period. The means for all four years have been at or below the threshold of detection of the monitoring equipment. Thus, there has been no apparent increase in SO_2 concentrations due to tract development.

B. Hydrogen Sulfide

1. Objectives

The objective of monitoring hydrogen sulfide in the ambient air on the tract is to establish the background value. Tract development, which will involve recovery of sulfur-bearing organics, may release hydrogen sulfide into the ambient air. Concentrations of this constituent in the future may be compared to pre-development conditions to assess environmental impacts.

2. Methods

The methods for collection of hydrogen sulfide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein. New H_2S analyzers were received late in the year, and consequently, could not be put on-line until just after the end of this reporting period. These will be operational during the coming year.

Table 2-3. Summary of Air Quality Data Collected Between December 1978 and November 1979, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.018	0.080	0.049
CO	ppm	0.5	1.5	0.5
NO	ppm	0.005	0.048	0.005
NO_x	ppm	0.005	0.048	0.005
H_2S	ppm	0.01	0.01	0.01
SO_2	ppm	0.01	0.01	0.01
TSP[3/]	$\mu g/m^3$	1	303	11.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1	87	12.[2/]
		Site 3		
O_3	ppm	0.005	0.076	0.038
H_2S	ppm	0.01	0.14	0.01
SO_2	ppm	0.01	0.09	0.01
TSP[3/]	$\mu g/m^3$	3	192	21.[2/]

[1/] Hourly average

[2/] Geometric Mean

[3/] 24-hour averages

Table 2-4. Summary of Air Quality Data Collected Between December 1977 and November 1978, Tract C-a

Parameter	Units	Minimum[1/]	Maximum[1/]	Arithmetic Mean
		Site 1		
O_3	ppm	0.017	0.088	0.057
CO	ppm	0.5	0.5	0.5
NO	ppm	0.005	0.016	0.006
NO_x	ppm	0.005	0.023	0.006
H_2S	ppm	0.01	0.04	0.01
SO_2	ppm	0.01	0.03	0.01
TSP[3/]	$\mu g/m^3$	1.	59.	14.[2/]
		Site 2		
TSP[3/]	$\mu g/m^3$	1.	60.	13.[2/]
		Site 3		
O_3	ppm	0.004	0.072	0.038
H_2S	ppm	0.01	0.55	0.01
SO_2	ppm	0.01	0.11	0.01
TSP[3/]	$\mu g/m^3$	1.	160.	26.[2/]

[1/] Hourly average

[2/] Geometric Mean

[3/] 24-hour averages

Table 2-5. Summary of Air Quality Data Collected Between February 1975 and January 1977 (Baseline), Tract C-a

Parameter	Units	Minimum[2]	Maximum[2]	Arithmetic Mean
		Site 1		
O_3	ppm	0.000	0.068	0.034
CO	ppm	0.000	4.2	0.6
NO	ppm	0.000	0.237	0.008
NO_x	ppm	0.000	0.234	0.009
H_2S	ppm	0.000	0.05	0.01
SO_2	ppm	0.000	0.09	0.01
TSP[3]	$\mu g/m^3$	1	211	9[2]
		Site 2		
TSP[3]	$\mu g/m^3$	1	102	9[3]
		Site 3		
O_3	ppm	0.000	0.089	0.031
CO	ppm	0.000	6.0	0.6
NO	ppm	0.000	0.159	0.006
NO_x	ppm	0.000	0.154	0.006
H_2S	ppm	0.000	0.03	0.01
SO_2	ppm	0.000	0.05	0.01
TSP[3]	$\mu g/m^3$	1	281	15[2]

[1] Hourly Average

[2] Geometric Mean

[3] 24-hour average

3. Results and Discussion

The H_2S data set is not amenable to statistical analysis for two reasons: 1) concentrations were below the threshold of detection most of the time during which the instrument was operational, and 2) lower than desirable data recovery which resulted from instrument malfunction. The maximum concentration of H_2S during the year was 0.14 ppm at Site 3 (Table 2-3), while both sites had mean annual concentrations below 0.01 ppm.

Comparisons with previous data show that the mean annual concentrations have remained at or below the threshold of detection for the entire study period. Marginally higher maximum H_2S concentrations have occurred at Site 3 during the MDP. This is probably related to surface discharge of underground water containing reduced sulfur compounds into a creek that flows past Site 3.

C. Nitrogen Oxides

1. Objectives

Nitrogen oxides are monitored to establish the existing natural background levels prior to major tract development and operation. Tract operations will involve substantial combustion with the possible generation of nitrogen oxides. Nitric oxide in the presence of sunlight and hydrocarbons may be a mechanism for smog production. These data may prove useful in correlating future visibility changes with pollutant concentration.

2. Methods

The methods followed for collection of nitrogen oxides data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The concentrations of both nitric oxide and nitrogen oxides were below the threshold of detection most of the time during the current year, so that the

annual mean of both these variables at Site 1 is at or below 0.005 ppm. The maximum concentration measured during the year was 0.048 ppm. These values compare well with the previous years--no annual mean for either NO or NO_x exceeded 0.01 ppm. The maximum concentrations of NO and NO_x, 0.237 ppm and 0.234 ppm, respectively, were measured during the baseline period. Since there has been no major source of NO or NO_x emissions on the tract, no increase in concentrations of these gases was expected.

D. Carbon Monoxide

Carbon monoxide results from the incomplete oxidation of carbon during combustion.

1. Objectives

Carbon monoxide is monitored to establish the ambient air concentration of this constituent prior to and during tract development activities. Vehicular use and fuel combustion during tract development may result in the emission of carbon monoxide in the tract area.

2. Methods

The methods followed for collection of carbon monoxide data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The measured concentration of carbon monoxide during the current year was at or below the threshold of detection most of the time. This is consistent with the mean concentrations found during the baseline periods and during the first year of the MDP phase. The maximum concentration found during the current year for carbon monoxide was 1.5 ppm. This compares with a maximum concentration of the first MDP year of 0.5 ppm and during the baseline period of 6.0 ppm. The 6.0 ppm maximum concentration measured during the baseline period may have been caused, at least in part, by the relatively high zero drift characteristic of the monitoring instrument.

As in the other gaseous constituents that have been discussed earlier, no major source of emissions has operated on tract during the MDP period. This is reinforced by the failure to measure an increase in carbon monoxide during the four-year monitoring period.

E. Ozone

1. Objectives

Ozone monitoring is conducted to establish the ambient air concentration of this constituent prior to and during tract development and operation. The potential emissions of nitrogen oxides coupled with hydrocarbons in strong sunlight can produce photochemical reactions.

2. Methods

The methods followed for collection of ozone data were described in RBOSC MDP Monitoring Report 2 and are not repeated herein.

3. Results and Discussion

The range of ozone concentrations recorded during the current year was 0.018 to 0.080 ppm at Site 1 and 0.005 to 0.076 ppm at Site 3. The mean concentration at Site 1 was 0.049 ppm and at Site 3 was 0.038 ppm. Thus, there were no violations of the primary National Ambient Air Quality Standard (NAAQS) for ozone (0.12 ppm) at either site. These concentrations are comparable to those found during the previous monitoring periods (Tables 2-3 through 2-5).

A more striking and important difference in ozone behavior between the two sites is shown in Figures 2-1 through 2-5, which illustrate the diurnal variation of mean hourly ozone concentrations as a function of the time of day. It is obvious that there is a much stronger diurnal variation at Site 3, with a daytime peak. This result was also noted in the previous year-end report (MDP Monitoring Report 3) and in the baseline report (RBOSP 1977).

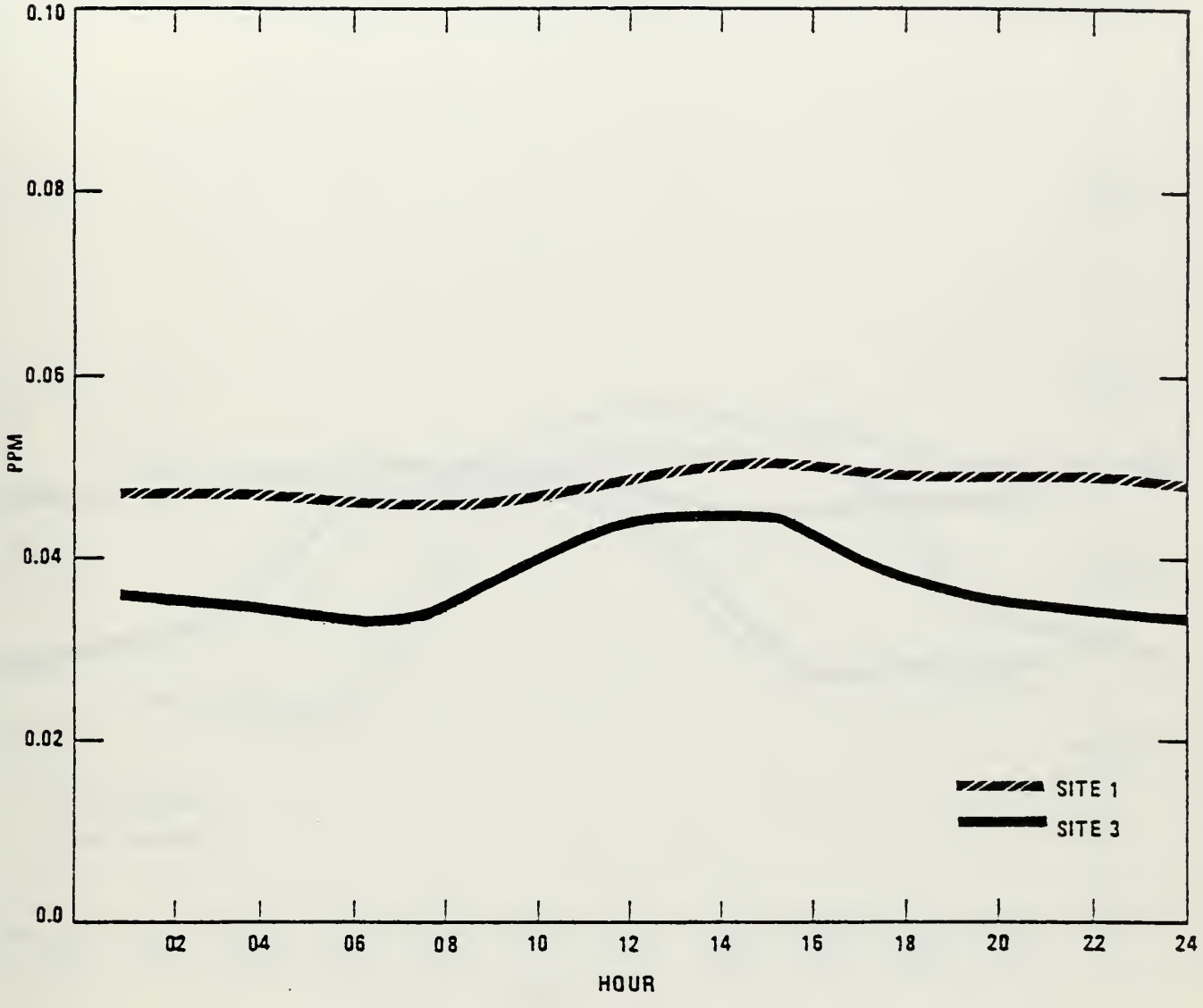


Figure 2-1. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Winter (Dec 1978 and Jan-Feb 1979), Tract C-a

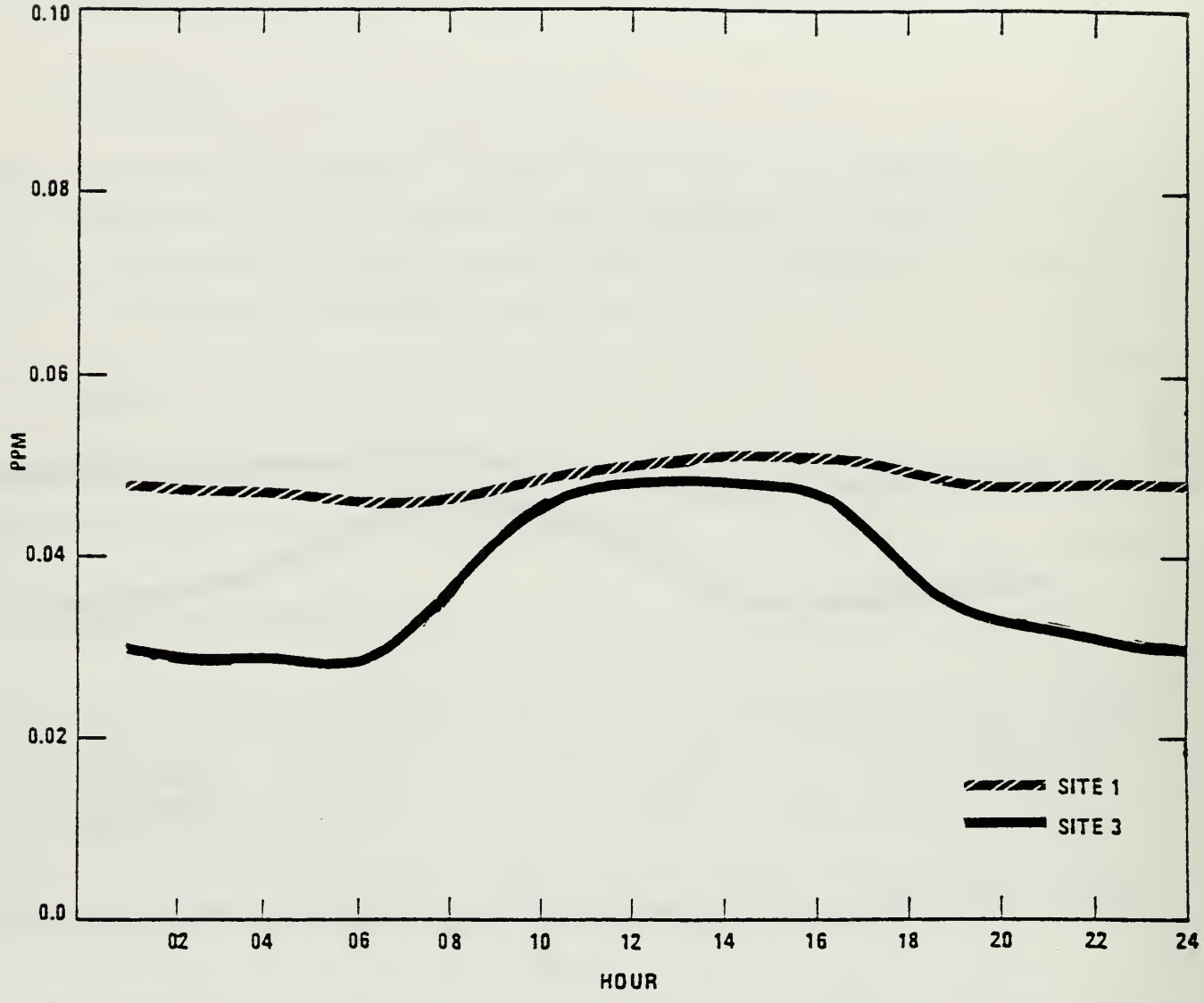


Figure 2-2. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Spring (Mar-May 1979), Tract C-a

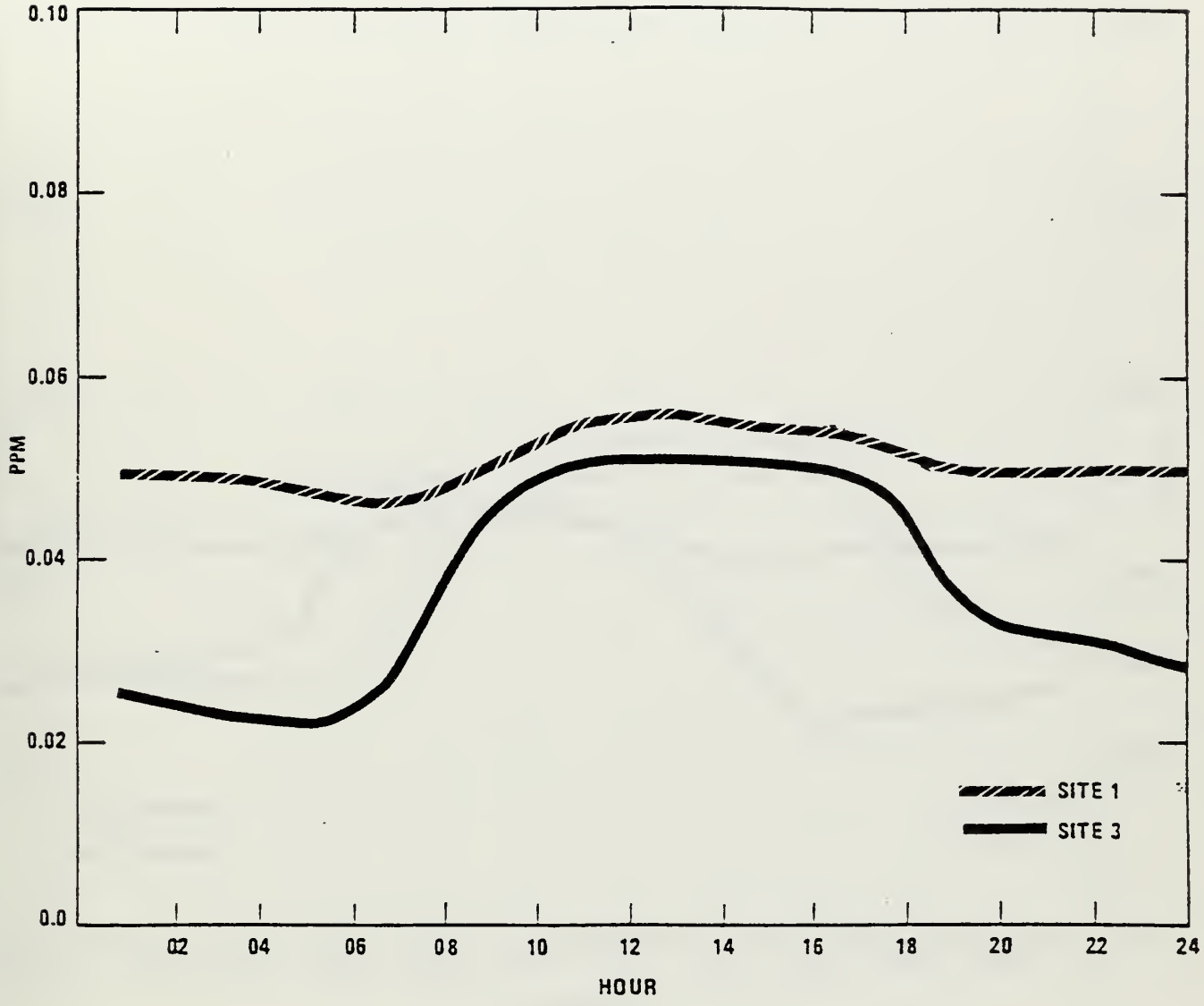


Figure 2-3. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Summer (June-Aug 1979), Tract C-a

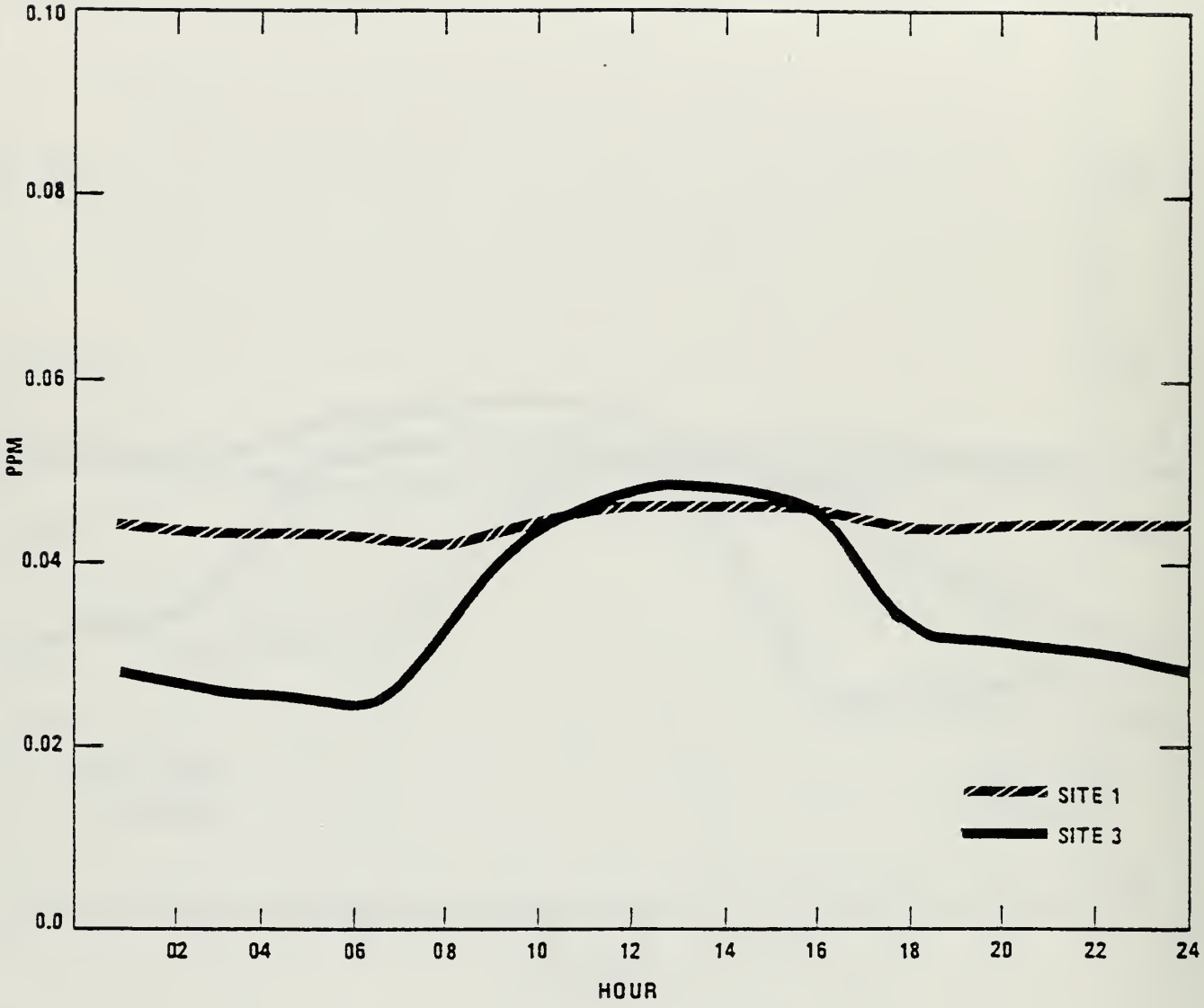


Figure 2-5.

Figure 2-4. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Fall (Sept-Nov 1979), Tract C-a

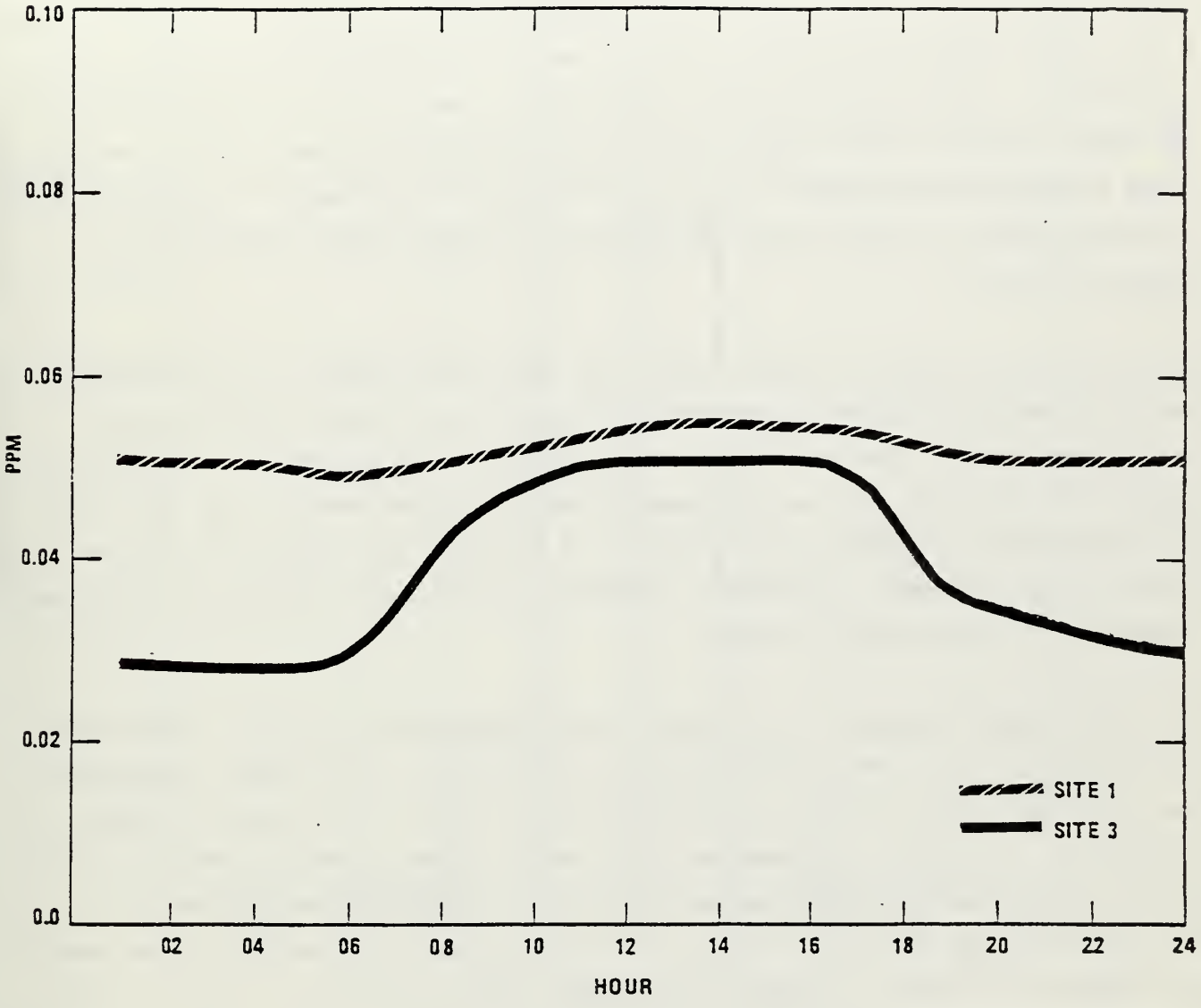


Figure 2-5. Diurnal Variation of Mean Hourly Ozone Concentrations at Sites 1 and 3, Annual Average (Dec 1978-Nov 1979), Tract C-a

Figures 2-6 through 2-13 are histograms of the hourly ozone concentrations at each of the sites during each of the four seasons. The hourly ozone concentrations are shown in 0.01 ppm increments. Site 1 shows a fairly sharp peak in the concentration distribution during each of the four seasons, with the peak increasing during the summer and decreasing during the winter. Site 3, on the other hand, shows a relatively sharp peak in the concentration distribution (at a low value) during the winter, but an almost flat histogram during the spring and summer. This illustrates that the diurnal ozone cycle is strongest during the summer season, which spreads the ozone concentrations over a large range. These histograms are another way of illustrating the pronounced diurnal variations of ozone typical of Site 3 and the relatively constant ozone concentrations typical of Site 1.

In the previous year-end report (RBOSC MDP Monitoring Report 3), the source of the relatively high ozone concentrations found on the tract and the diurnal variations found at the two sites were discussed. The conclusion, based on an analysis of the site data and on research done at other rural sites, was that the relatively high ozone concentrations at a remote site such as Tract C-a can be due to a number of factors, including stratospheric injection, photochemical reactions, or long-range transport.

The ozone summertime peak is a commonly found phenomenon (U.S. EPA 1978), and in conjunction with surface destruction reactions (U.S. EPA 1978), a mechanism for a diurnal cycle of ozone with a maximum magnitude in the summer can be postulated. At Site 3, the daytime peak results from boundary layer turbulence, which brings down relatively ozone-rich air into the gulch during the day. This daytime peak should be highest during the summer when ambient ozone levels are highest, as shown in Figures 2-1 through 2-13. At night, a strong surface inversion develops over the gulch, effectively isolating Site 3 from the elevated pool of relatively ozone-rich air. This allows the surface destruction reactions to reduce the ambient concentration of ozone.

This diurnal cycle is much weaker at Site 1 primarily because of its location near the top of the hill. The site is not often isolated from the elevated layer of ozone-rich air, because strong surface inversions are uncommon at a

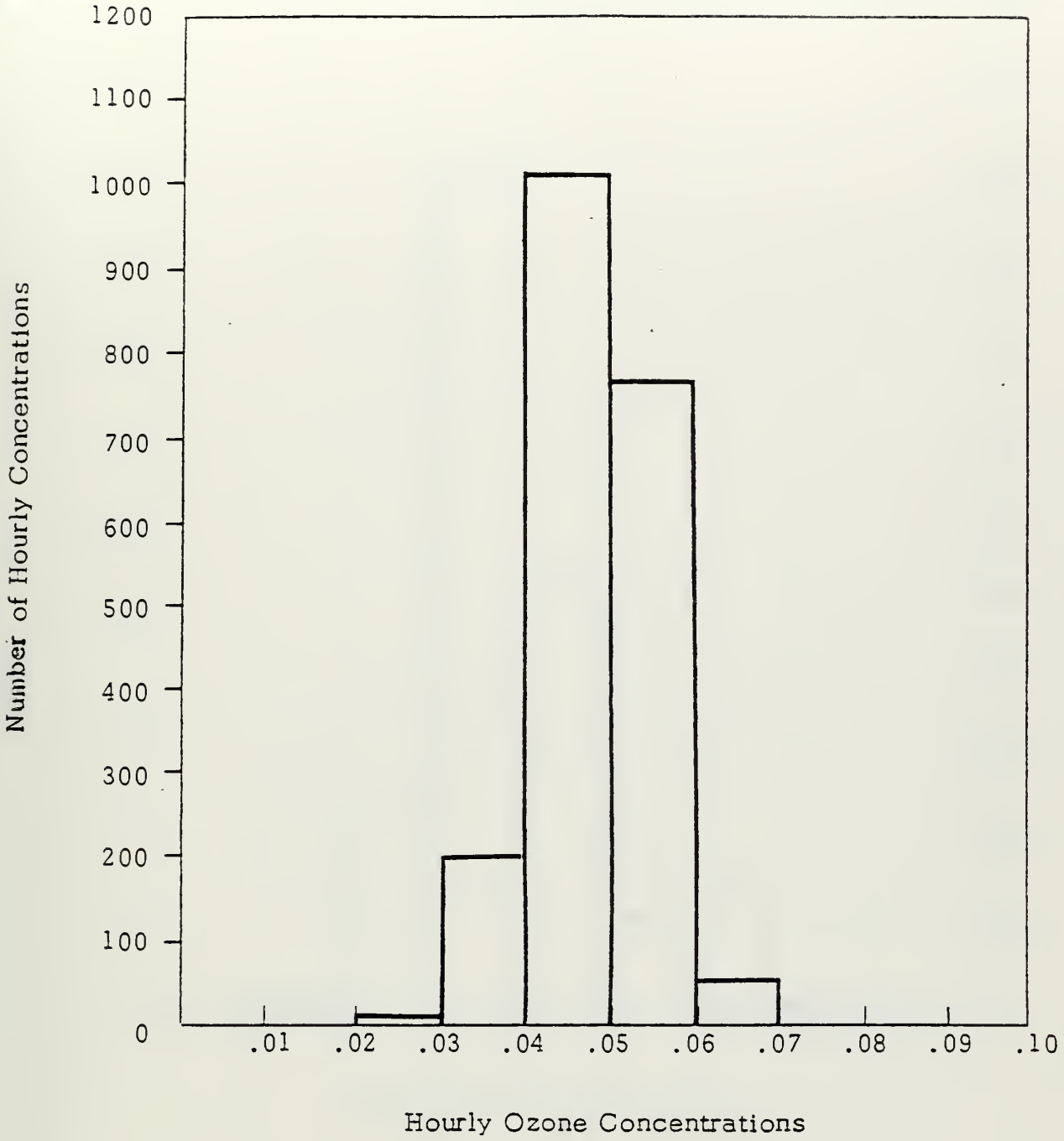


Figure 2-6. Histogram of Hourly Ozone Concentrations at Site 1, Winter (Dec 1978 and Jan-Feb 1979), Tract C-a

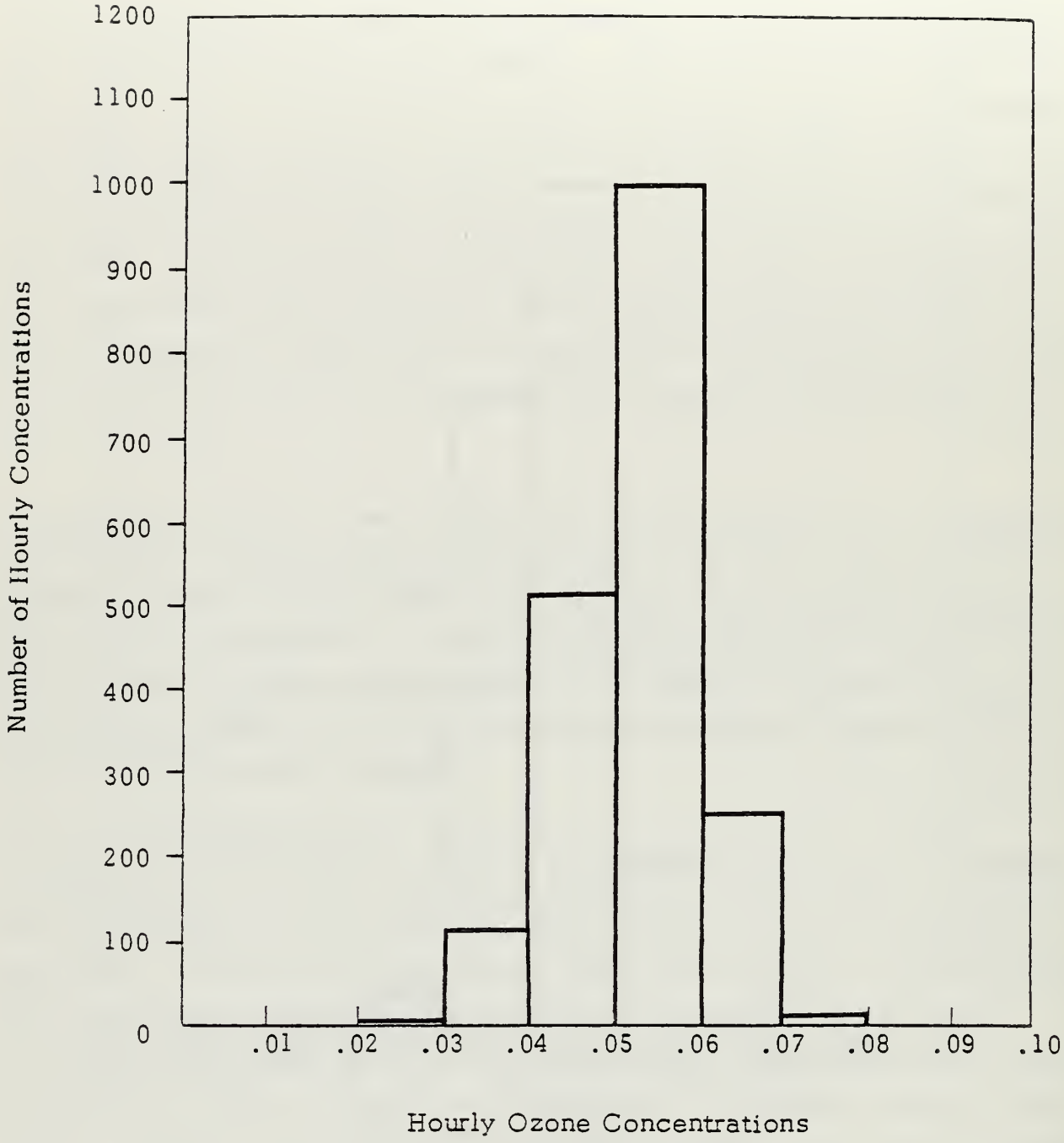


Figure 2-7. Histogram of Hourly Ozone Concentrations at Site 1, Spring (Mar-May 1979), Tract C-a

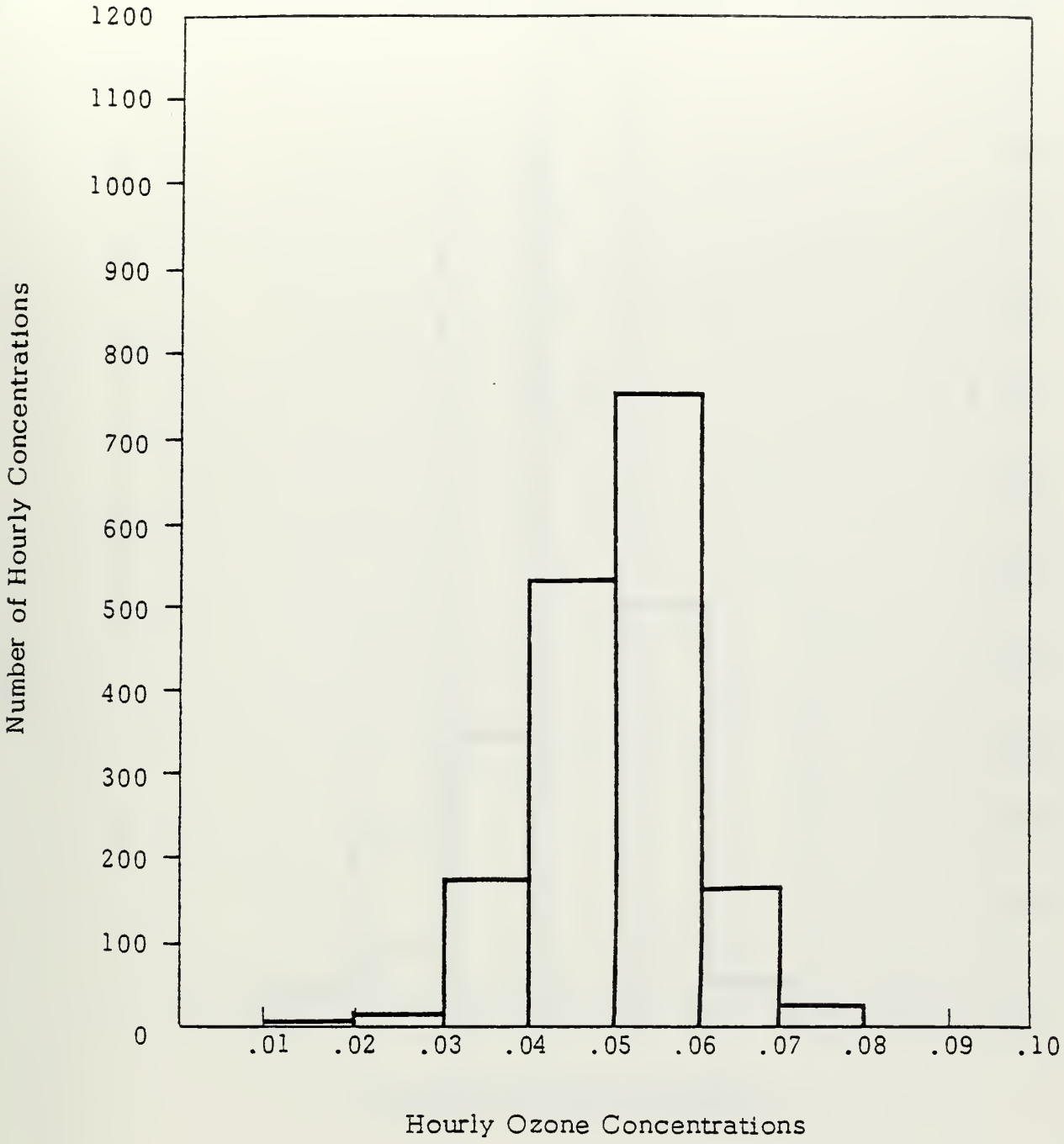


Figure 2-8. Histogram of Hourly Ozone Concentrations at Site 1, Summer (June-Aug 1979), Tract C-a

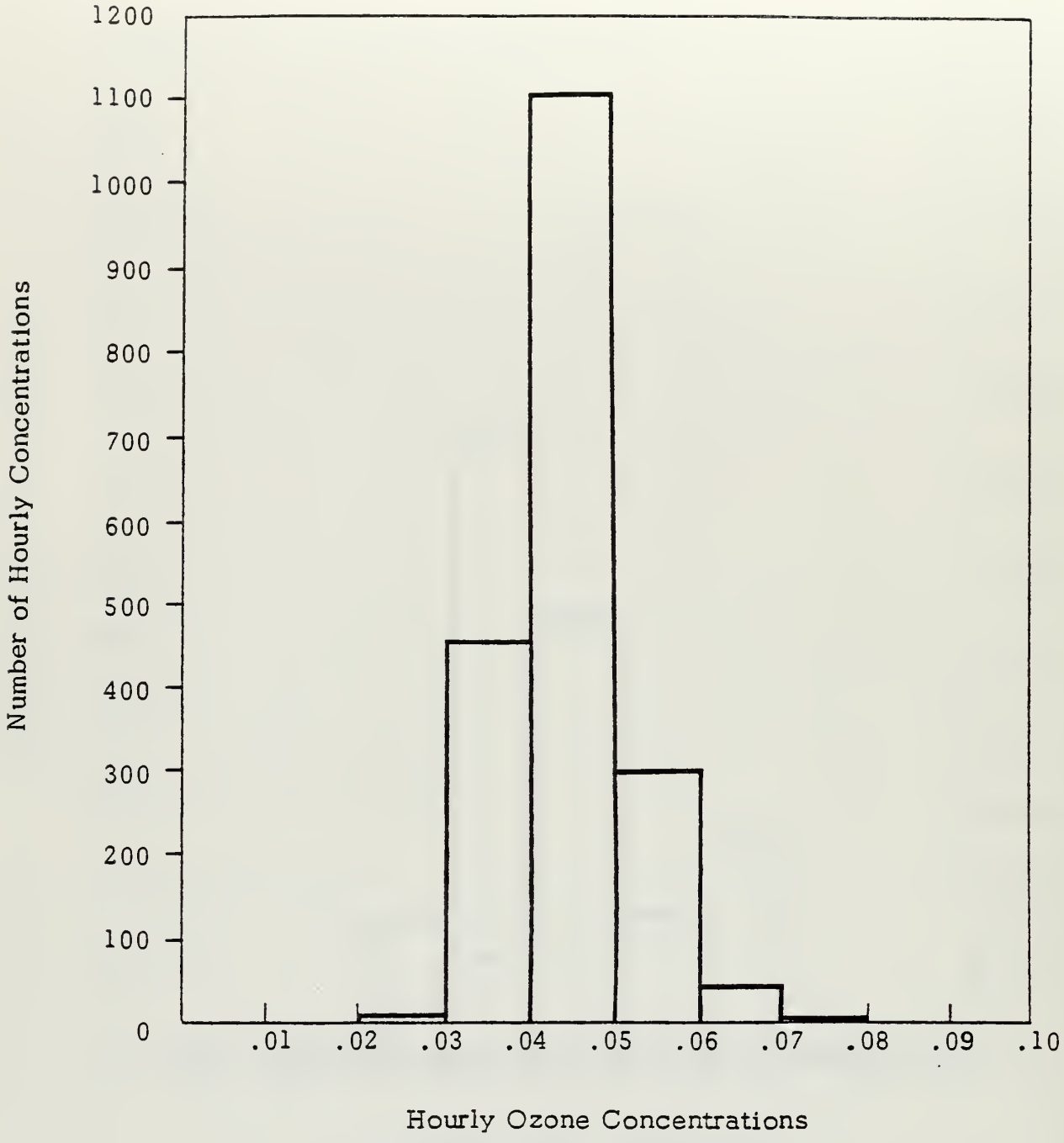


Figure 2-9. Histogram of Hourly Ozone Concentrations at Site 1, Fall (Sept-Nov 1979), Tract C-a

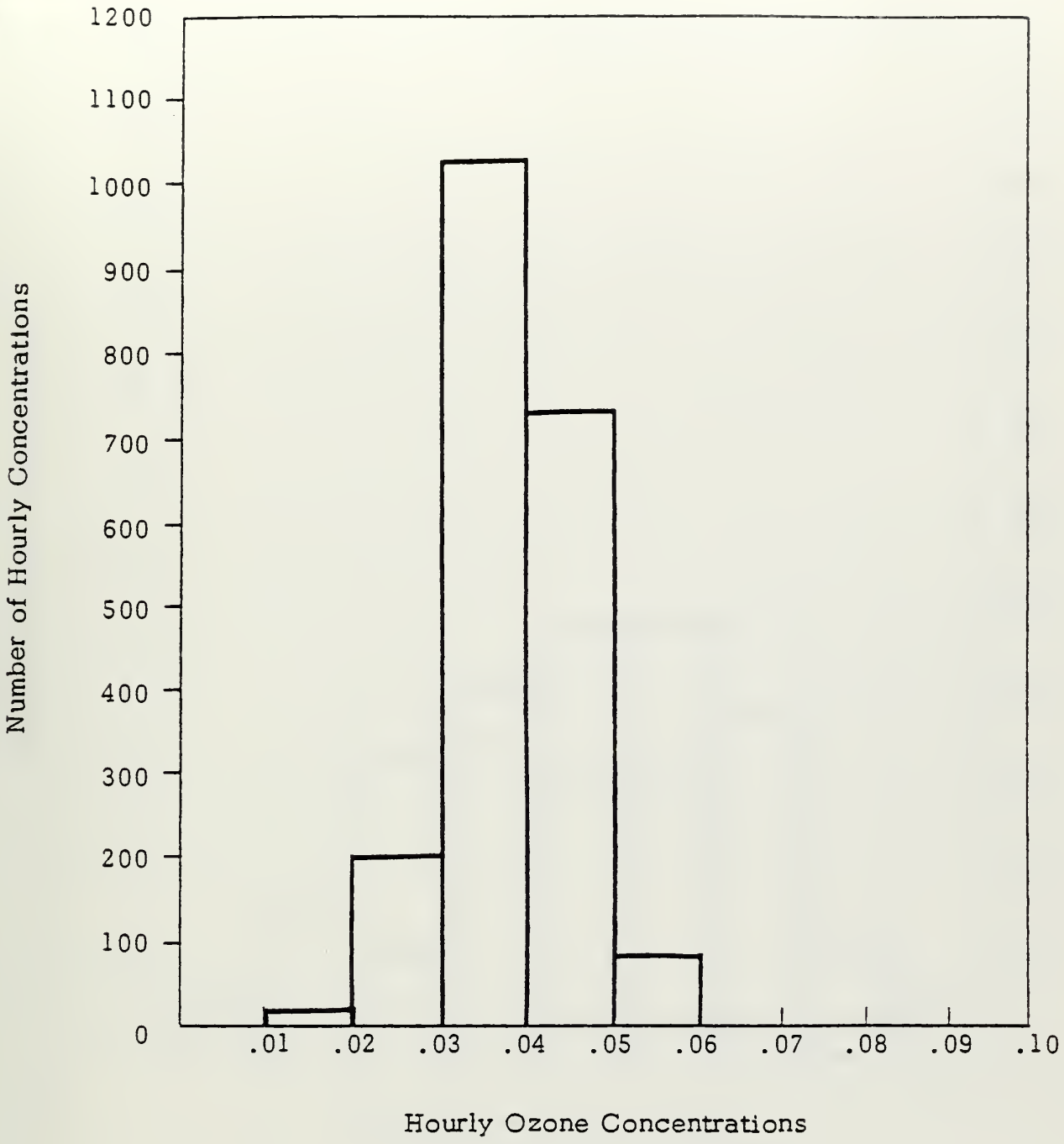


Figure 2-10. Histogram of Hourly Ozone Concentrations at Site 3, Winter (Dec-1978 and Jan-Feb 1979), Tract C-a

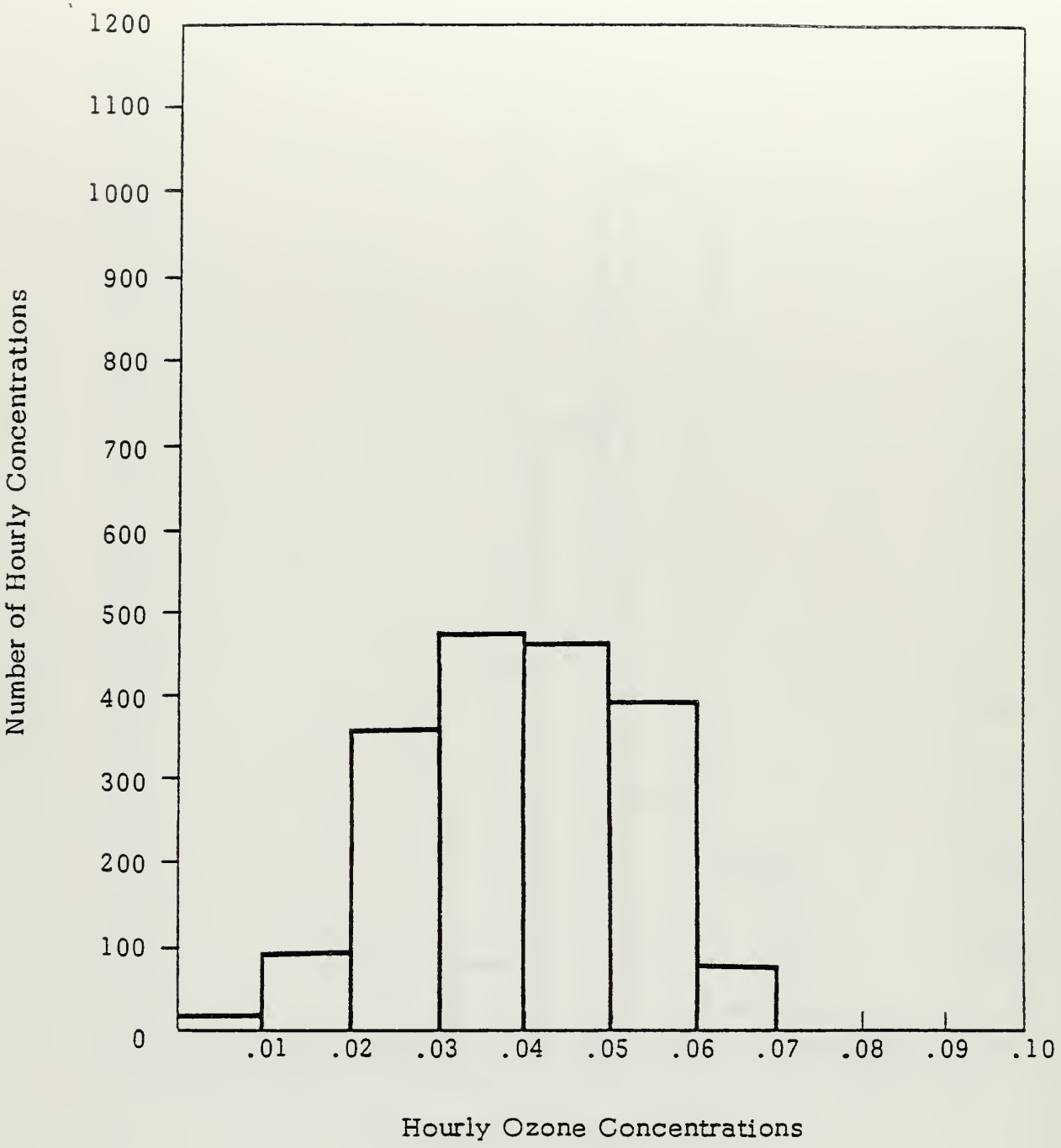


Figure 2-11. Histogram of Hourly Ozone Concentrations at Site 3, Spring (Mar-May 1979), Tract C-a

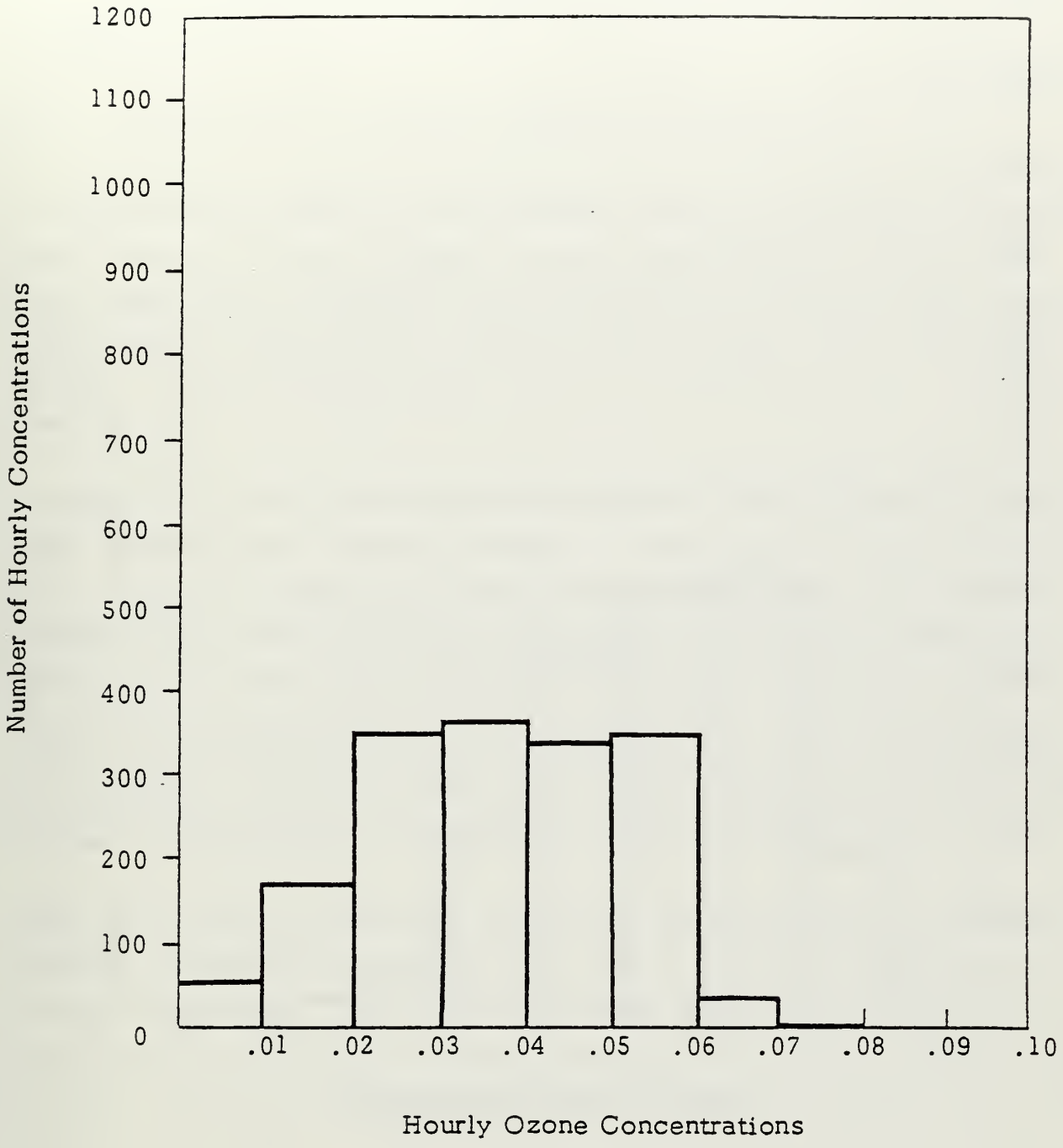


Figure 2-12. Histogram of Hourly Ozone Concentrations at Site 3, Summer (June-Aug 1979), Tract C-a

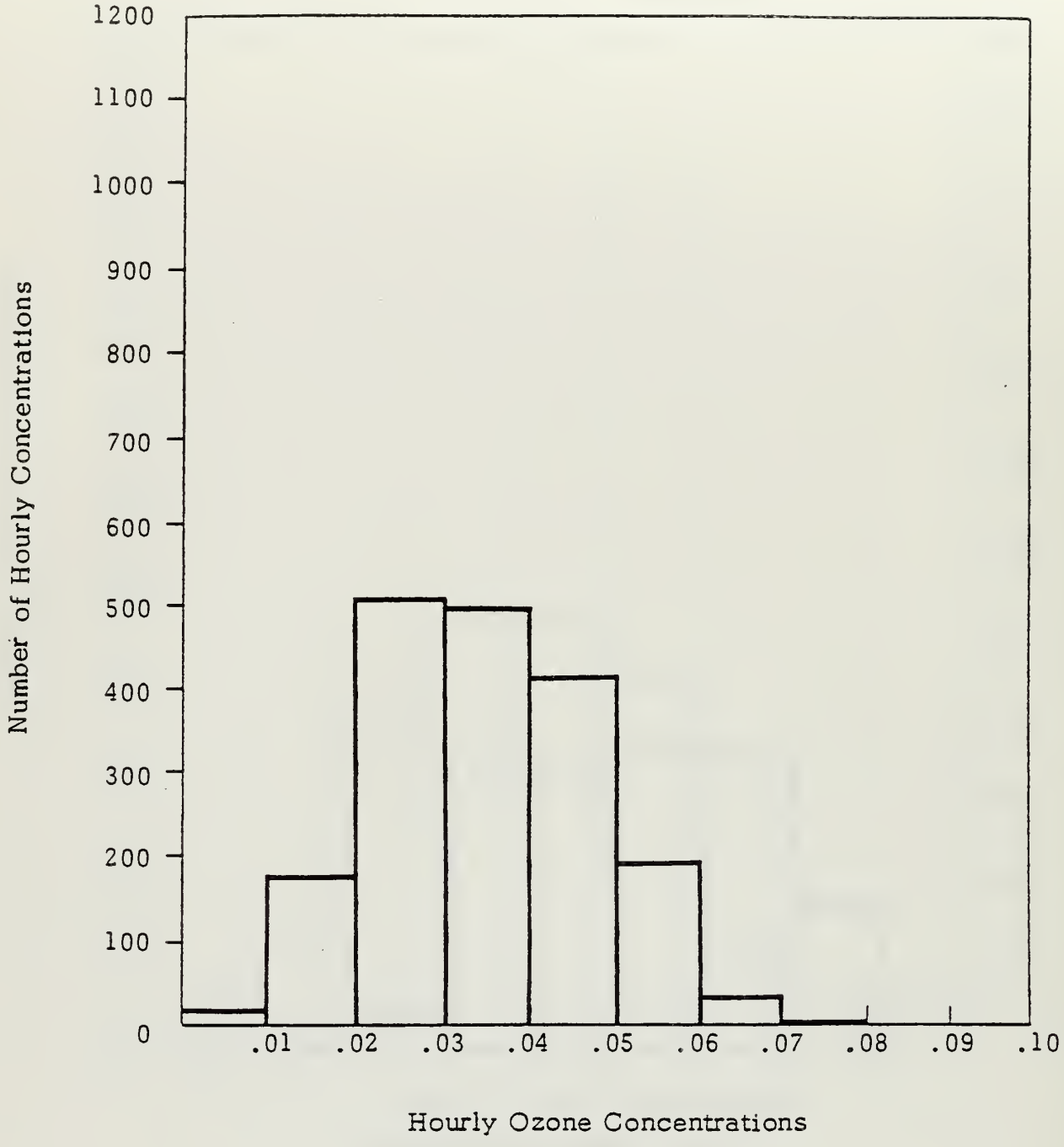


Figure 2-13. Histogram of Hourly Ozone Concentrations at Site 3, Fall (Sept-Nov 1979), Tract C-a

location above most of the local topographic relief (Δ T data from Site 1, Appendix 2-2.2). Based on this mechanism, one would conclude that the Site 1 ozone measurements would still exhibit the summertime peak, but would show only a small diurnal variation due to a minimum nighttime decrease in ozone concentration. This is precisely what is observed (Figures 2-1 through 2-5).

To investigate and understand this phenomenon better, case studies were made of unusual events relating to changes in ozone concentration at the two sites. One of these events is presented and discussed here. Table 2-6 gives the 15-minute average concentrations of ozone at each of the two sites, along with averages of selected meteorological variables during the evening of September 9 and 10, 1979.

Throughout this period, the ozone concentrations at Site 1 showed very little change, whereas several important changes in ozone concentrations occurred at Site 3. Table 2-6 shows that at the beginning of the period (2100 hours on September 9) the concentrations of ozone at the two sites were essentially identical. Three hours later, (2400 hours) the ozone concentration at Site 3 had decreased to approximately one-half that of Site 1. Four hours later, (0400 hours on September 10) the ozone concentrations at the two sites were again identical. Finally, at 0700 hours, the ozone concentration at Site 3 had decreased to approximately 60 percent of the Site 1 concentration.

Inspection of Table 2-6 indicates that most of the meteorological variables, including the temperature differential at Site 1 or the wind speed and wind direction at Site 3, do not show any consistent behavior that can account for these remarkable fluctuations in ozone concentration at Site 3. However, there is a close similarity between the temperature differential between Site 1 and Site 3 and the changes in ozone concentration at Site 3. There is a scientific basis for this similarity, since the temperature differential serves as an indicator of the inversion intensity at Site 3. Since the difference in elevation between the two sites is approximately 800 feet, the adiabatic lapse rate that would indicate neutral conditions is approximately 2.3 C. Consequently, when the temperature differential between the two sites is in the neighborhood of -2.3 C, this indicates that atmospheric turbulence will not be dampened over

Table 2-6. Detailed Listing of Meteorological and Air Quality Data During Evening of September 9-10, 1979 on Tract C-a

Date	Time	Site 1 O_3 (ppm)	Site 3 O_3 (ppm)	Site 1 ΔT 60-10m (°C)	Site 1 Temp (°C)	Site 3 Temp (°C)	Site 1-Site 3 ΔT (°C)	Site 3 Wind Speed (mph)	Site 3 Wind Direction (°)
9/9	2100	0.053	0.055	- 0.21	17.89	20.41	- 2.51	11.3	255
	2115	0.053	0.065	- 0.20	17.89	20.05	- 2.15	6.3	239
	2130	0.052	0.053	- 0.19	17.62	19.83	- 2.21	6.7	247
	2145	0.052	0.052	- 0.12	17.34	19.50	- 2.16	3.1	251
	2200	0.052	0.048	- 0.09	17.42	18.71	- 1.29	1.5	90
	2215	0.051	0.046	+ 0.09	17.26	17.94	- 0.68	1.2	163
	2230	0.051	0.042	+ 0.25	17.13	17.50	- 0.37	3.2	268
	2245	0.050	0.039	+ 0.27	16.94	16.38	+ 0.56	1.4	247
	2300	0.051	0.037	+ 0.33	16.89	15.57	+ 1.32	0.8	273
	2315	0.051	0.033	+ 0.49	16.96	14.75	+ 2.21	0.8	263
	2330	0.051	0.032	+ 0.26	17.13	14.28	+ 2.85	1.0	265
	2345	0.051	0.031	+ 0.42	17.22	13.44	+ 3.78	1.2	247
	2400	0.050	0.028	+ 0.21	16.82	12.67	+ 4.15	3.4	253
9/10	0015	0.049	0.027	+ 0.15	16.86	12.32	+ 4.54	4.3	260
	0030	0.047	0.026	+ 0.36	16.60	12.08	+ 4.52	5.1	263
	0045	0.047	0.026	+ 0.47	16.42	12.23	+ 4.19	5.3	270
	0100	0.047	0.027	+ 0.46	16.30	12.67	+ 3.63	5.8	272
	0115	0.048	0.030	+ 0.08	16.54	13.01	+ 3.53	5.3	261
	0130	0.047	0.032	+ 0.51	16.06	13.60	+ 2.46	2.5	261
	0145	0.047	0.032	+ 0.33	16.01	13.49	+ 2.52	4.2	256
	0200	0.047	0.031	+ 0.47	15.88	13.32	+ 2.56	7.7	263

Table 2-6. (continued)

Date	Time	Site 1 O_3 (ppm)	Site 3 O_3 (ppm)	Site 1 ΔT 60-10m (°C)	Site 1 Temp (°C)	Site 3 Temp (°C)	Site 1-Site 3 ΔT (°C)	Site 3 Wind Speed (mph)	Site 3 Wind Direction (°)
	0215	0.047	0.037	+ 0.24	15.85	14.85	+ 1.00	6.2	253
	0230	0.049	0.043	+ 0.79	16.80	16.47	+ 0.33	3.8	222
	0245	0.050	0.045	+ 0.52	17.73	16.90	+ 0.83	5.4	177
	0300	0.050	0.044	+ 0.43	17.70	16.71	+ 0.99	6.1	215
	0315	0.050	0.044	+ 0.13	17.82	17.42	+ 0.40	6.9	205
	0330	0.051	0.047	- 0.23	17.57	18.68	- 1.11	6.8	230
	0345	0.051	0.051	- 0.18	17.19	19.06	- 1.87	11.4	207
	0400	0.051	0.053	- 0.29	16.83	19.47	- 2.64	7.8	233
	0415	0.052	0.052	- 0.32	16.93	18.73	- 1.80	8.6	213
	0430	0.051	0.052	- 0.31	16.15	17.85	- 1.70	5.4	209
	0445	0.049	0.052	- 0.28	15.43	17.17	- 1.74	4.8	188
	0500	0.049	0.051	- 0.24	14.85	16.55	- 1.70	3.2	212
	0515	0.049	0.050	- 0.01	14.84	16.14	- 1.30	2.6	196
	0530	0.047	0.047	- 0.20	14.50	15.65	- 1.15	1.1	215
	0545	0.045	0.037	- 0.11	14.25	14.73	- 0.48	0.7	1
	0600	0.041	0.035	- 0.03	13.98	14.56	- 0.58	0.9	90
	0615	0.043	0.030	- 0.19	13.86	13.31	+ 0.55	2.7	281
	0630	0.043	0.027	- 0.15	13.58	13.32	+ 0.26	3.9	277
	0645	0.040	0.025	- 0.12	13.26	13.02	+ 0.24	3.7	290
	0700	0.042	0.025	- 0.16	13.68	13.29	+ 0.39	5.2	286

Site 3. When the temperature differential is much less than -2.3 C (less negative) or positive, the formation of a stable atmospheric condition over Site 3 is indicated, so atmospheric turbulence should be severely restricted. When the latter case occurs, there should then be very little mixing between the elevated reservoir of ozone-rich air and the surface layer at Site 3. Because of the ozone destruction reactions, the ambient ozone concentrations at Site 3 should decrease quickly.

This hypothesized mechanism accounts for the behavior in ozone concentrations at both sites very well. The decrease in ambient ozone concentrations at Site 3 on two different occasions, during one night, is a direct result of decreases in the mixing ability of the boundary layer and in the supply of relatively ozone-rich air. No other mechanism has been put forward that can account for this behavior.

This discussion therefore leads us to believe that the conclusions found in Monitoring Report 3 are valid and supported by the additional data collected during the current year. The hypothesis of an elevated pool or reservoir of relatively high ozone concentrations appears to explain observed events. This reservoir of ozone is at least partially responsible for the diurnal cycle of ozone concentrations at Site 3 observed throughout the entire monitoring program. The concept of local production of ozone having an important effect on the diurnal variation is not supported by the observed events.

In addition to the diurnal variation, there is an the annual cycle of high ozone concentrations during the summer and low concentrations during the winter, which has been commonly observed at many sites. However, the ozone concentrations found on the tract at present are well below the national ambient air quality standards, so this is not of immediate concern.

F. Particulates

1. Objectives

The objectives of atmospheric particulate monitoring are to establish a natural background concentration and to monitor the effects of construction in the modular development phase of tract operation.

2. Methods

The methods followed for collection of total suspended particulate data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

3. Results and Discussion

Quarterly and annual geometric mean and maximum values of the total suspended particulate data for the current year at each of the three sites are presented in Table 2-7. Two events have occurred in this current year that have had an effect on the total suspended particulate data.

The major event was the construction of a natural gas pipeline for a private oil and gas drilling company. The pipeline passes immediately adjacent to Site 1 and within approximately one-quarter of a mile of Site 2. Construction of this pipeline took place in September and October of the current year and resulted in very high concentrations of total suspended particulate matter at Site 1 during those two months. In fact, the highest concentrations found during the current year (303 $\mu g/m^3$) were measured at Site 1 during this construction period. These elevated concentrations were not caused by any activity or development of the tract, and therefore are to be considered spurious data in determining the effects of tract development on air quality.

The second event of interest was the paving during the last week of June of the main access road to Tract C-a, which runs approximately 100 yards from Site 3. This may reduce the particulate concentrations found at Site 3 during the summer, although there are still several dirt roads within a half mile of the monitoring site.

Table 2-7. Quarterly and Annual Geometric Means and Maximum Values of 24-hour Average Total Suspended Particulate Concentrations from December 1978 to November 1979 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Sixth Quarter MDP (December 1978 - February 1979)			
Geometric Mean	4	4	8
Maximum	8	12	65
Seventh Quarter MDP (March - May 1979)			
Geometric Mean	8	9	19
Maximum	34	33	94
Eighth Quarter MDP (June - August 1979)			
Geometric Mean	18	24	46
Maximum	53	52	192
Ninth Quarter MDP (September - November 1979)			
Geometric Mean	22	15	27
Maximum	303	87	145
Annual (December 1978 - November 1979)			
Geometric Mean	11	12	21
Maximum	303	87	192

The highest geometric means and maximum particulate concentrations at each of the three sites occurred during the summer, with the exception of the maximum values taken in the early Fall at Sites 1 and 2 when the pipeline construction activity was at a peak. The lowest values occurred during the winter, when there was a semi-permanent snowcover on the tract. For comparison, the quarterly and annual geometric means and maximum values of the previous reporting year and the baseline period are presented in Tables 2-8 and 2-9.

Although much higher particulate concentrations were measured at Site 1 for a short period when the pipeline was being constructed, the annual geometric mean at Site 1 (11 $\mu g/m^3$) is very close to that of Site 2 (12 $\mu g/m^3$). In addition, the annual mean at Site 1 during the current year is actually lower than the mean of the previous year (14 $\mu g/m^3$), contrary to what might be expected by the impact of the pipeline construction.

There are a number of reasons why there has been a decrease in the annual geometric mean particulate concentrations at Site 1. First of all, the use of the geometric mean rather than the arithmetic mean tends to reduce the influence of a few samples (such as collected this year) which are out on the upper tail of the distribution of particulate concentrations. In addition, Tables 2-7 and 2-8 show that the spring and summer quarters of 1979 had lower geometric mean concentrations than the same quarters in 1978. Thus, during much of the current year, Site 1 recorded lower particulate concentrations than in the previous year. (Incidently, Site 2 had a slightly higher geometric mean particulate concentration during the 1979 summer quarter compared with the 1978 summer quarter, which illustrates the variability typically found in monitoring total suspended particulates). A third reason which explains the decrease in mean particulate concentrations at Site 1 is a suspected sampling bias, which is more appropriately discussed after additional information is presented.

Inspection of the geometric mean particulate concentrations at Site 3 reveals a sharp decline from 1977-78 to 1978-79 (Tables 2-7 and 2-8). The annual mean decreased by 20 percent, from 26 $\mu g/m^3$ to 21 $\mu g/m^3$. Even more striking is the decrease in the summer quarter mean of 40 percent, from 77 $\mu g/m^3$ to 46 $\mu g/m^3$. It is possible that the paving of the main tract access road (located

Table 2-8. Quarterly and annual geometric means and maximum values of 24-hour average total suspended particulate concentrations from December 1977 to November 1978 ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
Second Quarter MDP (December 1977 - February 1978)			
Geometric Mean	4	3	5
Maximum	9	5	33
Third Quarter MDP (March - May 1978)			
Geometric Mean	12	11	16
Maximum	38	39	54
Fourth Quarter MDP (June 1978 - August 1978)			
Geometric Mean	22	22	77
Maximum	59	60	160
Fifth Quarter MDP (September - November 1978)			
Geometric Mean	17	15	39
Maximum	51	34	155
Annual (December 1977 - November 1978)			
Geometric Mean	14	13	26
Maximum	59	60	160

Table 2-9. Quarterly and Annual Geometric Means and Maximum Values of 24-Hour Average Total Suspended Particulate Concentrations for the Baseline period (February 1975 to January 1977) ($\mu g/m^3$) on Tract C-a

	Site 1	Site 2	Site 3
February 1975			
Geometric Mean	--	3	5
Maximum	--	10	12
Spring 1975 (March-May)			
Geometric Mean	29	11	23
Maximum	95	84	163
Summer 1975 (June-August)			
Geometric Mean	22	15	47
Maximum	211	95	247
Fall 1975 (September-November)			
Geometric Mean	6	16	18
Maximum	52	102	137
Winter 1975-76 (December-January)			
Geometric Mean	2	2	4
Maximum	10	11	14
Spring 1976 (March-May)			
Geometric Mean	11	11	11
Maximum	80	51	130
Summer 1976 (June-August)			
Geometric Mean	22	22	27
Maximum	81	57	105
Fall 1976 (September-November)			
Geometric Mean	12	15	35
Maximum	53	46	281
Winter 1976-77 (December-January)			
Geometric Mean	5	6	5
Maximum	18	57	59

Table 2-9 (Continued)

	Site 1	Site 2	Site 3
1975-76 Annual			
Geometric Mean	9	9	18
Maximum	211	102	247
1976-77 Annual			
Geometric Mean	8	9	12
Maximum	81	57	281

approximately 100 yards from Site 3) during the last week in June of the current year contributed to the decrease in particulate concentrations at the Site. However, this will be difficult to confirm, because the varying meteorological conditions introduce a large noise component into the system. In addition, breaking the summer's data set into subsets before and after the paving operation seriously reduces the sample size. Analysis procedures will be considered when additional data have been collected in an attempt to determine the impact of the paving operation.

Comparisons of the maximum particulate concentrations show the influence of the construction activity at Site 1. The maximum concentration found during the current year was 303 $\mu g/m^3$, while the maximum for the previous year was 59 $\mu g/m^3$. However, if only the summer period is considered (before construction on the pipeline began, and normally the time of year when the maximum particulate concentration occurs), then the maximum particulate concentration measured at Site 1 drops to 53 $\mu g/m^3$, comparable to the maximum concentration found during the previous year.

Tables 2-7 through 2-9 show that there is an increase in the annual geometric mean at all three sites between the baseline period and the MDP period. The increase is relatively small at Sites 1 and 2 (2 - 6 $\mu g/m^3$) and moderate at Site 3 (3 - 14 $\mu g/m^3$). The range of the quarterly mean concentrations at Site 3 during both the baseline and MDP periods is much greater than at the other two sites.

Inspection of Tables 2-7 through 2-9 shows the changes in the relative magnitudes of the geometric means at the three sites with respect to time of year. That is, the annual geometric mean particulate concentrations during the MDP for the two background sites (Sites 1 and 2) are approximately one-half that of the treatment site (Site 3). During the winter (Second and Sixth MDP Quarters) the geometric means for all three sites are very close, while during the summer (Fourth and Eighth MDP Quarters) Sites 1 and 2 have geometric mean concentrations much below the mean of Site 3. In general this is also true for the baseline period. The relationship of the winter and the summer periods to the particulate concentrations will be discussed in more detail as the statistical analyses are presented.

The primary NAAQS for TSP was exceeded only once during the current year. This occurred at Site 1 during the pipeline construction period. The secondary NAAQS for TSP was exceeded once at Site 3 during a very dry period (approximately 0.05 inch of precipitation had been recorded in the 30-day period preceeding the sampling day).

The annual cumulative frequency distributions of the particulate concentrations at each of the three sites are presented in Figure 2-14. The distributions of particulates for Sites 1 and 2 are similar except on the upper tail (above 90 percent probability) where the construction activity near Site 1 caused a few samples to be abnormally high. The figure shows that the 50 percent probability point for the particulate concentration (where half the samples are above and half are below this value) is approximately 10 $\mu g/m^3$ for Site 1, 13 $\mu g/m^3$ for Site 2, and 20 $\mu g/m^3$ at Site 3. The 50 percent probability point for the first year of baseline data (RBOSP 1976) was very similar, approximately 10 $\mu g/m^3$ for Site 1, 12 $\mu g/m^3$ for Site 2, and 22 $\mu g/m^3$ for Site 3. However, last year (RBOSC MDP Monitoring Report 3) the same point is much higher, approximately 18 $\mu g/m^3$ for Sites 1 and 2, and approximately 40 $\mu g/m^3$ for Site 3.

Investigation into this inconsistency has indicated that it is not caused by a major shift in the data (as originally suspected when this was discovered last year) nor by an anomalous set of data collected last year, but instead simply reflects a sampling bias. When the particulate sampling program was first restarted at the beginning of the MDP program (in the winter of 1977-78), only a few valid particulate samples were collected due to equipment problems and to a once-per-six-days sampling schedule. In late Spring 1978, the sampling schedule was increased to once-per-four-days, and in late Fall 1978, to once-per-three-days. Consequently, relatively few samples were taken that first winter when the particulate concentrations should have been low, while a large number of samples was taken during the summer when particulate concentrations are generally higher. This effectively biased the data on the high side.

During the winter of 1977-78 an average of 17 valid samples was taken at each site, while during that summer an average of 53 samples was taken. Statistics based on the entire 1977-78 data set thus have the potential to be biased, and

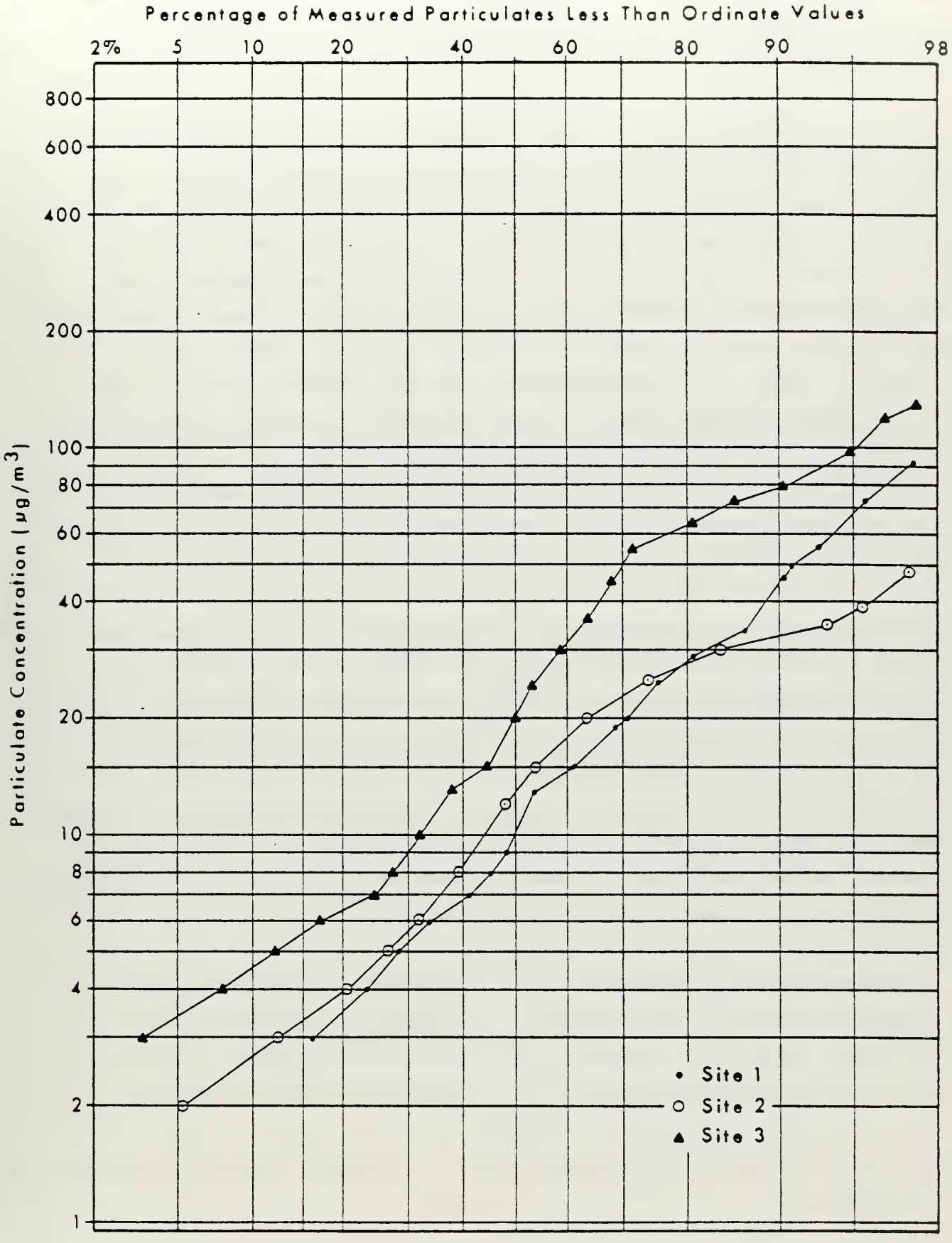


Figure 2-14. Cumulative Frequency Distributions of Total Suspended Particulate Data From the Three Tract C-a Monitoring Sites, December 1978 - November 1979

must be carefully evaluated. As discussed earlier, the annual geometric mean particulate concentrations at all three sites have decreased from 1977-78 to 1978-79, which is due at least in part to the sampling bias.

a. Correlation analysis - One of the considerations in developing this analysis is to evaluate the impacts of the winter and summer seasons on the particulate concentrations. It is quite possible that different physical processes and mechanisms may affect the data during different times of the year. In particular, during the winter the semi-permanent snowcover should reduce the impacts of localized particulate sources (i.e., the main tract access road near Site 3, or the pipeline right of way adjacent to Site 1), such that the sites are influenced more by the same general regional sources. Thus, particulate concentrations between sites might be expected to be more highly correlated during the winter than during the summer. Figures 2-15 through 2-17, which present the separate cumulative distributions for the winter and summer seasons, indicate that at each site the cumulative distributions can be subdivided into the two seasons with minimum overlap.

Table 2-10 presents the correlations of the particulate concentrations among the three sites for each of the four years of record. The correlations are given for the entire data year, the summer season (defined for purposes of this analysis as the period within each data year during which snowcover was absent), and the winter season (defined for the purpose of this analysis as the period within each data year during which snowcover was present). Because of the year-to-year variability in meteorological factors, the length of the two seasons varied considerably. Based on snow depth and precipitation records, the summer season for each year was determined to be:

Baseline year one (2/75-1/76)	April 11 - October 23, 1975
Baseline year two (2/76 - 1/77)	March 30 - December 1, 1976
MDP year one (12/77 - 11/78)	March 25 - November 8, 1978
MDP year two (12/78 - 11/79)	April 14 - October 28, 1979

The period before and after the summer season of each year was taken to be the winter season.

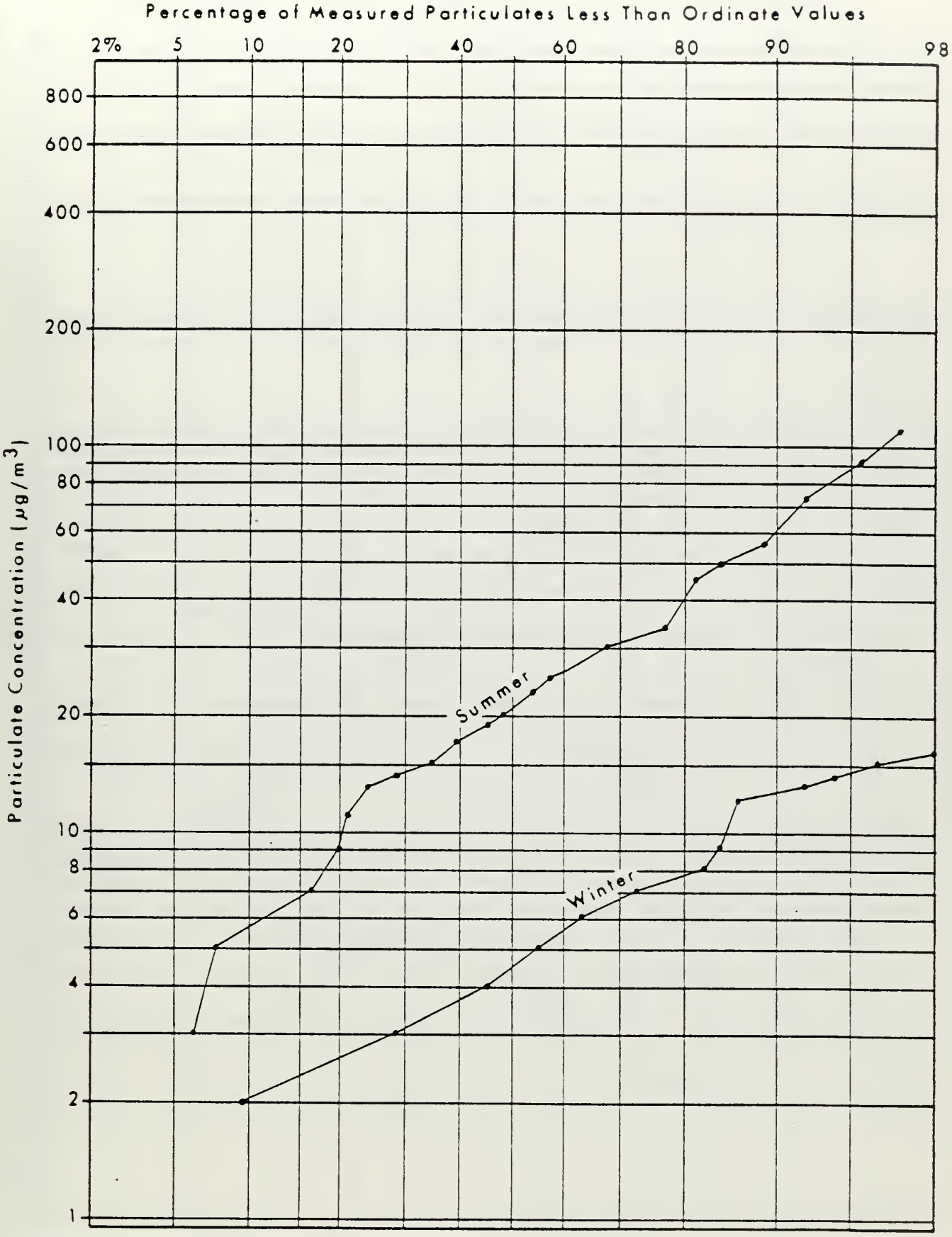


Figure 2-15. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 1 During the 1979 Summer and Winter Season, Tract C-a

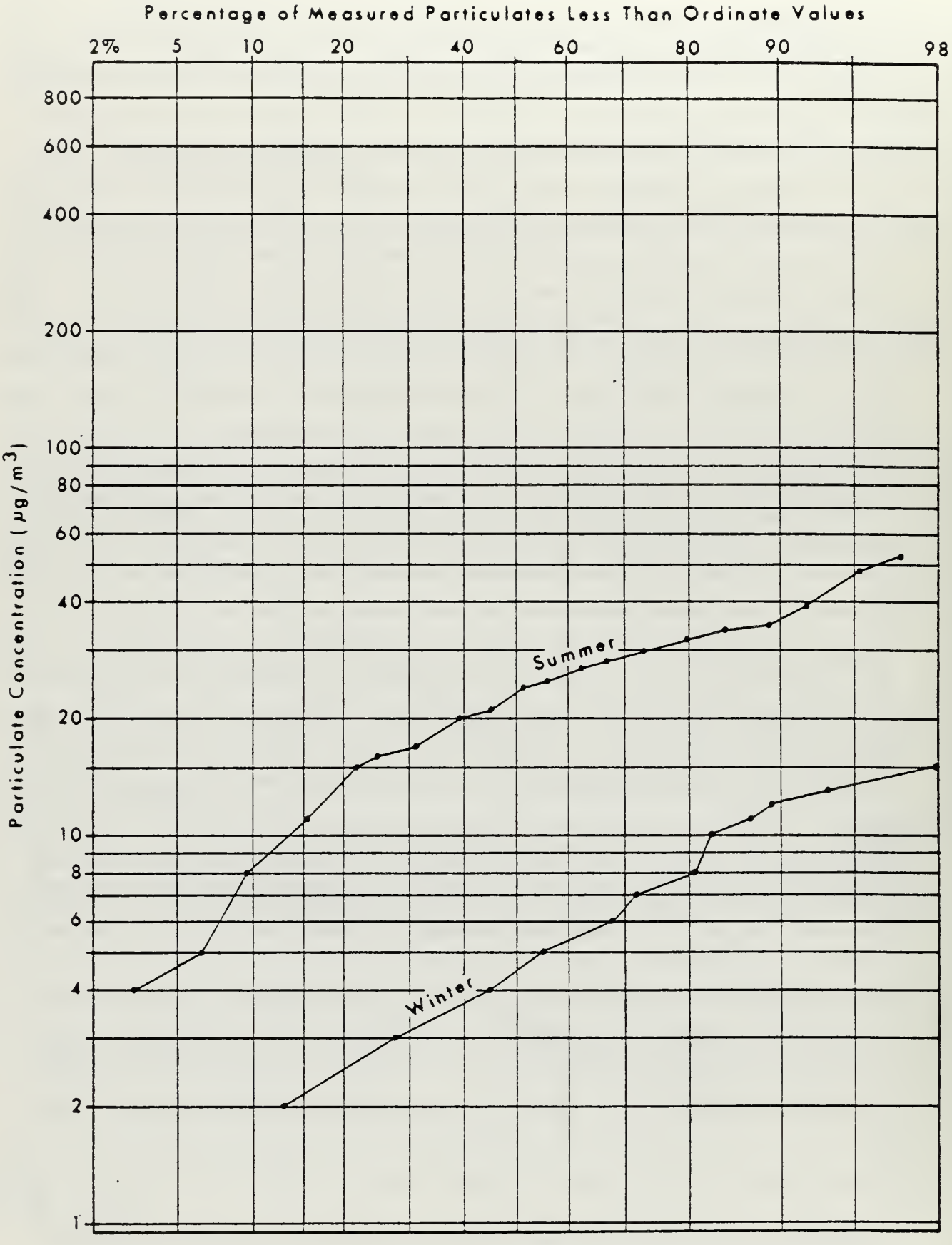


Figure 2-16. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 2 During the 1979 Summer and Winter Season, Tract C-a

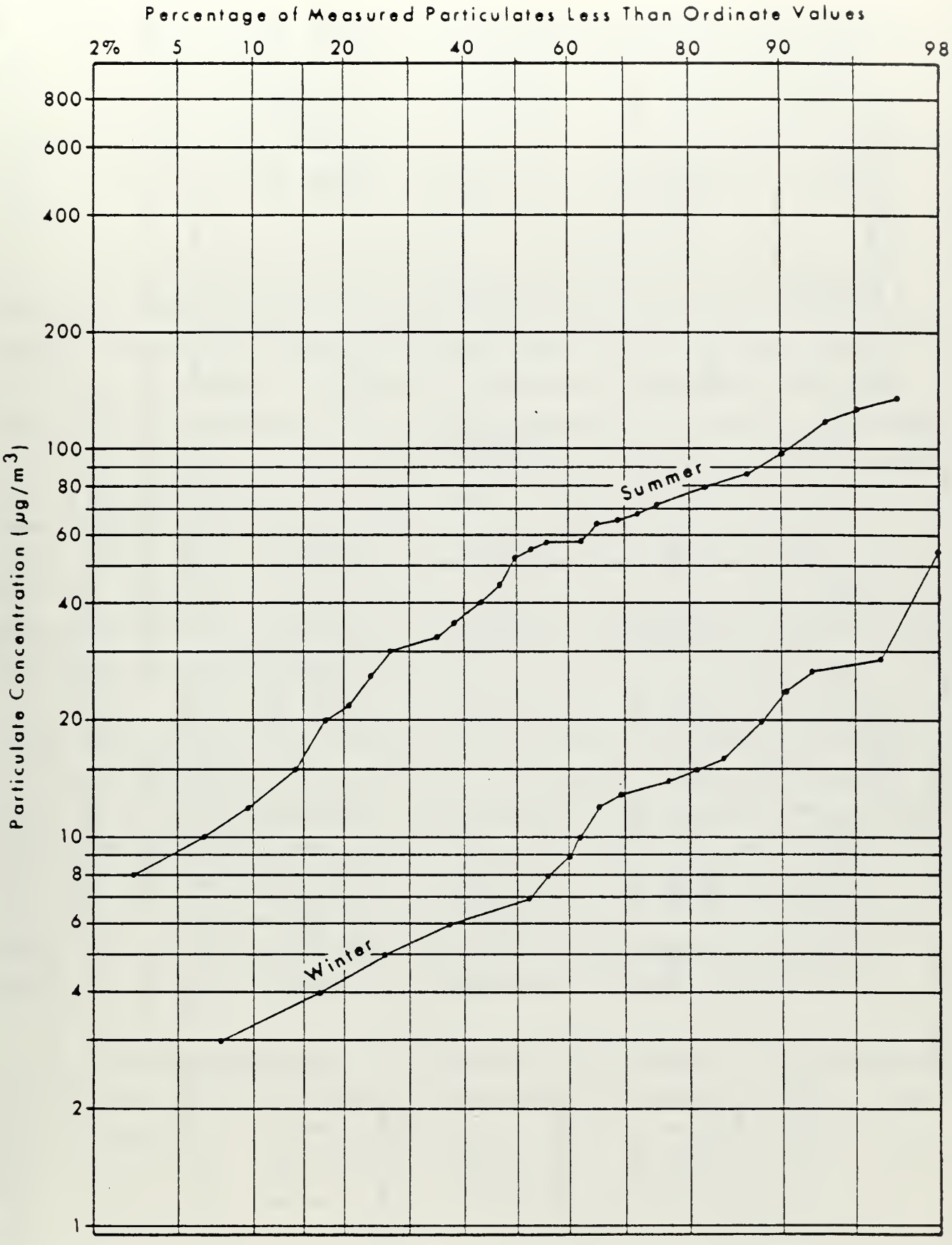


Figure 2-17. Cumulative Frequency Distributions of Total Suspended Particulate Data from Site 3 During the 1979 Summer and Winter Seasons, Tract C-a

Table 2-10. Correlation Coefficients (r), Coefficients of Determination (r^2), and Sample Number (N) for the 24-hour Average Total Suspended Particulate Concentrations at Sites 1, 2, and 3, Tract C-a

	Baseline						Modular Development Phase					
	(2/75 - 1/76)			(2/76 - 1/77)			(12/77 - 11/78)			(12/78 - 11/79)		
Correlation	r	r^2	N	r	r^2	N	r	r^2	N	r	r^2	N
For Total Year												
Sites 1 vs 2	0.53	0.28	91	0.63	0.40	91		NA[1]		0.84	0.70	103
Sites 1 vs 3	0.31	0.10	89	0.49	0.24	114				0.62	0.38	107
Sites 2 vs 3	0.56	0.32	105	0.47	0.22	72				0.69	0.48	100
For Summer Only												
Sites 1 vs 2	0.43	0.19	59	0.57	0.33	53	0.81	0.65	50	0.78	0.61	58
Sites 1 vs 3	0.14[3]	0.02	57	0.43	0.18	86	0.44	0.19	47	0.45	0.21	57
Sites 2 vs 3	0.40	0.16	63	0.36	0.13	42	0.44	0.19	48	0.51	0.26	55
For Winter Only												
Sites 1 vs 2	0.17[3]	0.03	32	0.36	0.13	38		NA[2]		0.84	0.71	45
Sites 1 vs 3	0.16[3]	0.03	32	0.23[3]	0.05	28				0.60	0.36	50
Sites 2 vs 3	0.73	0.53	42	0.47	0.22	30				0.76	0.57	45

[1] 1977-1978 annual correlations not presented due to inadequate data set from winter season

[2] An average of only 4 paired samples exist for correlative purposes during the winter season of 1977-1978

[3] These correlations are not significantly different than zero at $\alpha = 0.05$

No correlations are given in Table 2-10 for the winter season, or the entire year of the first MDP year, because an average of only four paired samples exist for correlative purposes during the winter season. This was caused by equipment problems associated with the start up of the MDP environmental program and to a once-per-six-day sample schedule on alternate days until late March 1978.

The results shown in Table 2-10 for the MDP period appear to be reasonable, since higher correlations are expected between Sites 1 and 2 (the control sites generally upwind of the tract) than between Sites 2 and 3 and Sites 1 and 3 (Site 3 is the treatment site located in a gulch that drains much of the tract). The correlation coefficient (r) for 1978-79 between Sites 1 and 2 (r_{12}) averages 0.8, while the other correlation coefficients (r_{13} and r_{23}) for 1978-79 average 0.5 - 0.6. Although r_{13} and r_{23} do increase from the summer to the winter season (from 0.5 to 0.7), they still are not as high as r_{12} in the winter (0.84). These lower correlations between treatment and control sites indicate that there is still an impact during the winter on the particulate concentrations measured at Site 3 by tract activities and the main tract access road, although this impact is not as strong in the winter.

During the baseline, the distinction between control and treatment sites was not valid, although Site 3 may still have received some excess particulate matter due to a limited amount of traffic on County Road 24 (now the main tract access road) that passes near Site 3. Table 2-10 shows the correlations for the baseline period, and it is evident that r_{23} is often equal to or higher than r_{12}. It is interesting to note that the correlations during the baseline period are in general considerably less than the correlations during the MDP period. No explanation has been developed to date for this behavior.

b. Regression Analyses - The objective of this analysis is to investigate the predictive ability of a number of meteorological and site activity variables on the concentration of particulates at each of the three monitoring sites. In addition, the relative importance of these variables in explaining the particulate concentrations can be examined. For the purposes of this analysis, a set of variables has been used to establish the meteorological conditions and site activity on each sampling day. These variables were defined as:

PREC	-	precipitation on the sampling day (hundredths of an inch)
PREC3	-	total precipitation on the sampling day and the two previous days (hundredths of an inch)
DAYSIN	-	number of days since measurable precipitation occurred
TEMP	-	average daily temperature (C)
WS	-	average daily wind speed (mph)
WHR12	-	number of hours during sampling day that the average wind speed exceeded 12 mph
SR	-	total daily solar radiation (langleys)
TD	-	average daily dewpoint (C)
MANPWR	-	number of workers and visitors at the tract on the sampling day
NOVEH	-	number of vehicles at the tract during sampling day
HVY	-	indicator of heavy construction equipment used on the tract during sampling day

All of the meteorological variables used in the regression analysis were site specific, with the exception of solar radiation and dewpoint. That is, they were collected at the same site as the particulate concentrations. The regression analysis was run for the total year, and for both the summer and winter seasons separately, similar to the approach used in the correlation analysis. Six sampling dates in September were deleted from the Site 1 data set, since the pipeline activity had an undue influence on these particulate samples unrelated to tract activity.

1. Multiple Regression - Table 2-11 gives the coefficient of determination (r^2) resulting from the multiple regression analysis. The results show that 59 percent of the variation on a yearly basis of the particulate concentrations at Site 1 can be explained by the combination of meteorological and site activity variables. Similarly, 66 percent of the variation at Site 2 and 70 percent of the variation at Site 3 can be explained by the meteorological and site activity variables. It is interesting to note that the coefficients of determination for the summer and winter seasons are not appreciably different, with the exception of Site 3 during the winter (r^2 = 0.39). Review of the data

Table 2-11. The Coefficient of Determination (r^2) Values Resulting from the Multiple Regression of the Meteorological and Site Activity Variables on the Total Suspended Particulate Concentrations at each Site on Tract C-a during 1979

	r^2		
	Site 1	Site 2	Site 3
Total Year	0.59	0.66	0.70
Summer	0.60	0.68	0.67
Winter	0.62	0.57	0.39

from Site 3 indicates that a few days with relatively high particulate concentrations (50-80 $\mu g/m^3$) in late winter are probably associated with this decreased predictive ability. These high particulate concentrations may be associated with local melting of the snowpack, particularly around the nearby main tract access road. As might be expected, the assumption of a sharp transition between the winter and summer seasons is not completely realistic and adds some uncertainty to the results.

These results indicate that about one-third of the variation in the particulate concentration still remains unexplained by the selected independent variables. This is essentially the same result found in last year's multiple regression analysis.

2. Stepwise Multiple Regression - A further use of regression analysis is a technique known as stepwise multiple regression, in which a regression algorithm selects the meteorological and site activity variables by their importance as predictors of the dependent variable (particulate concentration). The end result is a ranking by importance of the eleven independent variables (as given earlier), regardless of their classification as a meteorological or site activity variable. Tables 2-12 through 2-14 present the results of the stepwise regressions for Sites 1, 2 and 3. The regressions were run against three data sets from the current year: the summer season, the winter season, and the entire year. The same predictors used in the multiple regression analysis were used in this analysis. For each step in each of the regressions, the tables list the predictor entered, the coefficient of determination (r^2) for the regression containing the predictors entered thus far, the increase in r^2 from the preceeding step, and the percent increase in r^2 with the added predictor. Predictors added to each regression are included in the table up to the step where the next predictor's significance probability exceeds $\alpha = 0.05$.

A number of conclusions can be reached (Tables 2-12 through 2-14):

- At Sites 2 and 3, the predictors meeting the significance criterion ($\alpha = 0.05$) are considerably more successful in explaining the variation in particulate concentrations during the summer and the entire year

Table 2-12. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2 and 3 during the 1978-79 Year, Tract C-a

Site 1 Data (100 cases)

Step	1	2	3	4
Predictor	DAYSIN	TEMP	WHR12	WSMAX
r^2	.332	.398	.441	.468
Increase in r^2	.332	.066	.043	.027
(α) associated with adding variable to regression	.0001	.0015	.0080	.030

Site 2 Data (92 cases)

Step	1	2
Predictor	TEMP	WS
r^2	.513	.595
Increase in r^2	.513	.082
(α) associated with adding variable to regression	.0001	.0001

Site 3 Data (102 cases)

Step	1	2	3	4
Predictor	TEMP	TD	DAYSIN	HVY
r^2	.489	.598	.647	.684
Increase in r^2	.489	.109	.049	.037
(α) associated with adding variable to regression	.0001	.0001	.0004	.0010

Table 2-13. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2 and 3 during the 1979 Summer Season, Tract C-a

Site 1 Data (51 cases)

Step	1	2
Predictor	DAYSIN	WHR12
r^2	.288	.403
Increase in r^2	.288	.115
(α) associated with adding variable to regression	.0001	.0037

Site 2 Data (50 cases)

Step	1	2	3	4
Predictor	WS	TEMP	SR	WHR12
r^2	.435	.539	.606	.668
Increase in r^2	.435	.104	.067	.062
(α) associated with adding variable to regression	.0001	.0021	.0075	.0057

Site 3 Data (52 cases)

Step	1	2	3	4
Predictor	TEMP	DAYSIN	HVY	TD
r^2	.353	.484	.560	.613
Increase in r^2	.353	.131	.076	.053
(α) associated with adding variable to regression	.0001	.0010	.0057	.014

Table 2-14. Results of Stepwise Regressions of Particulate Concentrations for Sites 1, 2 and 3 during the 1979 Winter Season, Tract C-a

Site 1 Data (49 cases)

Step	1	2	3
Predictor	TEMP	TD	HVY
r^2	.173	.324	.380
Increase in r^2	.173	.151	.056
(α) associated with adding variable to regression	.0030	.0024	.050

Site 2 Data (43 cases)

Step	1	2
Predictor	TEMP	PREC
r^2	.254	.344
Increase in r^2	.254	.090
(α) associated with adding variable to regression	.0006	.024

Site 3 Data (51 cases)

Step	1	2
Predictor	DAYSIN	TEMP
r^2	.167	.262
Increase in r^2	.167	.095
(α) associated with adding variable to regression	.0029	.016

than in the winter. However, at Site 1 the predictors do not show a marked change in efficiency from one season to the next, and are generally not as successful in accounting for the variation in particulate concentrations.

- At Sites 1 and 2, regressions using the summer and yearly data sets show that only meteorological variables, primarily measures of wind speed, temperature and precipitation, are important predictors. Typically, not all three of these measures were found to be important in any individual case. The number of days since measurable precipitation (DAYSIN) was the most important predictor at Site 1 in both the summer and yearly data sets, while average daily temperature (TEMP) and wind speed (WS) were the most important predictors at Site 2. The number of hours during which the average wind speed exceeded 12 mph (WHR12) was an important variable during the summer at both Sites 1 and 2. This is generally considered the minimum wind speed at which wind erosion of bare surfaces can occur.

- At Site 3, the important predictors in the summer and yearly data sets are temperature, number of days since the last measurable precipitation, dewpoint, and an indicator of heavy equipment on the tract. It should be noted that heavy equipment use was only the third or fourth best predictor in the regression, and roughly equivalent to dewpoint in efficiency of explaining the variance. Dewpoint was negatively correlated with particulate concentrations, indicating that low dewpoints (very dry air) were associated with high particulate concentrations. The r^2 value using just these four predictors is high, indicating that approximately two-thirds of the variation in the particulate concentrations occurring in the yearly and summer data sets can be explained by these four variables.

- No site activity variables were found to be important at Sites 1 or 2 in the stepwise regressions carried out on the summer or total year data sets. At Site 3, one indicator of onsite construction activity (HVY) was found to be important, but it did not rank higher than

third in significance. This result is reasonable, since Site 3 is located in a gulch that drains the tract under downvalley flow. Somewhat surprisingly, the number of vehicles on tract (which use the main tract access road passing approximately 100 yards to the north of Site 3) was not a significant predictor of the variations in particulate concentrations.

- During the winter season, indicators of site activity enter the regression equation for Site 1 relatively early. However, no site activity indicators are important at Sites 2 and 3 during the winter season.

One extremely important consideration when evaluating these results is the relative importance of the particulate concentrations during the summer and winter seasons. That is, the particulate concentrations at each site during the winter season (with a semi-permanent snow cover) are generally quite low and tend to have minimum variations. On the other hand, the summer season is characterized by large variations in the particulate concentrations with occasional periods of very high concentrations. Thus, the variation in the particulate concentrations during the winter is more difficult to predict and is also of less concern, because it is associated with very low particulate concentrations.

c. Analysis of Variance - An Analysis of Variance (ANOVA) was performed to determine if there were significant differences between sites and years, and between summer and winter seasons within each year. A three-way ANOVA with a nested design was used for this determination. Table 2-15 presents the results of the ANOVA. Significant differences exist at the 0.001 level among the sites and between seasons within each year. No significant difference ($\alpha = 0.05$) was found between years.

Duncan's multiple range test was used to determine significant differences among those main effects showing significance in the ANOVA. Duncan's test (Table 2-16) shows that the sites can be divided into two groups having significantly different means ($\alpha = 0.05$). The first group consists of particulate concentrations from Sites 1 and 2, and the second group contains particulate

Table 2-15. Results of Three-Way Analysis of Variance of Total Suspended Particulate Data for November 1979, Tract C-a

Source of Variation	Degrees of Freedom	Sums of Squares	F-Value
Site	2	33,811	30.70***
Year	3	3,177	1.92
Year x Site	6	4,584	1.39
Season (Year)	4	147,498	66.95***
Season x Location x Year	8	21,874	4.96***
Error	1131		

*** = Significant at the 0.001 level

Table 2-16. Duncan's Multiple Range Tests on Significant Main Effect Sources of Variation for Total Suspended Particulate Concentrations during 4-Year Period of Record at Tract C-a

Source of Variation		Sample Size (N)	Arithmetic Mean ($\bar{X}$)	Groupings[1/]
Main Effect:	Sites			
	1	397	18.4	A
	2	366	17.4	A
	3	392	35.9	B
Main Effect:	Seasons			
	Summer	762	32.3	A
	Winter	393	7.9	B

[1/] Means followed by the same letter are not significantly different ($\alpha = 0.05$)

concentrations from Site 3. As shown in Table 2-16, the two seasons also have significantly different particulate concentrations.

d. Conclusions - A number of statistical analyses were performed on the total suspended particulate data. An ANOVA showed that there is a significant difference in the particulate concentrations between winter and summer seasons and between Sites 1 and 2 (control) and Site 3 (treatment). This difference between seasons was also shown graphically by plotting the cumulative frequency distributions separately for the two seasons. No significant differences were found between the data from the baseline and MDP periods.

The multiple regression analysis showed that between 59 and 70 percent of the variation in the particulate concentrations of the total 1979 data set could be explained by a combination of site-specific meteorological and site activity variables. Using the summer season data only, approximately 60 to 67 percent of the variation could be explained by these variables.

The results of stepwise multiple regression analysis showed that meteorological variables representing precipitation, wind speed, and temperature (or solar radiation) were all relatively important in explaining the variation in particulate concentrations. None of the three site activity variables (HVY, NOVEH, MANPWR) were significant in explaining the variation during the summer season or for the entire year at Sites 1 or 2. This fact that site activity variables are not important at Site 1 is somewhat at odds with the regression analysis performed on last year's data, but this year's analysis has been improved by a better selection of variables and the use of site specific data.

At Site 3, a measure of site activity (HVY) was significant, but explained much less of the variation than did temperature or precipitation indicators. Thus, neither site activity nor the main tract access road has a strong impact on the particulate concentrations at Site 3.

During the winter, a measure of site activity (HVY) predicted particulate concentrations better at Site 1 than at Sites 2 or 3. This result is less important for three reasons: 1) the r^2 in the winter was less than in the

summer, indicating that the success in explaining the variation was less, 2) the total variation of the particulate concentrations is less in the winter so that subtle effects and sampling errors make it more difficult to predict particulate concentrations, and 3) particulate concentrations during the winter are far below the NAAOS for TSP.

Generally, the most important variable in the regression at each site is the 24-hour average temperature. This is an example of an easily measured variable indicating other physical variables such as soil moisture.

2.2 METEOROLOGY

Meteorological parameters are monitored to provide information on the general climate of Tract C-a and vicinity. They will also provide a basis for estimating the potential impact of emissions that may result from tract development and operation. Three meteorological sites have been in operation since the first quarter of the MDP. Meteorological data are taken at the 10-m level at each site, and also at the 60-m level at Site 1, the main sampling site. Site 1 is at an elevation of 7,335 feet above mean sea level (MSL) just west of the tract boundary. Site 2 is at an elevation of 7,360 feet MSL to the southwest of the tract. Site 3 is located just east of the tract boundary in a broad gulch, at an elevation of 6,580 feet MSL. The terrain in the immediate vicinity of Site 1 slopes gently downward to the northeast, while further away to the northeast, east, and southeast there are many deep ravines or gulches which cut the general level of the plateau 200 feet or more. A topographic map showing the locations of the three sites for the MDP program has been presented (Environmental Monitoring Sites Map 1--Physical, in map pocket). This section of the report deals primarily with the meteorological data collected from the three sites during the MDP period December 1978-November 1979 (hereafter referred to as the current year). Meteorological data for Site 1 are presented in Appendix 2-2.1, and data for Sites 2 and 3 are presented in Appendix 2-2.2. The data for the baseline period and the first year of the MDP period were extracted from earlier reports (RBOSP 1977 and RBOSC MDP Monitoring Report 3) for comparative purposes.

A. Temperature and Stability

1. Objectives

Ambient air temperature, a primary climatic parameter, provides basic information on monthly and year-to-year variability of climatic conditions at the C-a tract. The measured vertical temperature differential within the lowest boundary layers can be utilized to determine the stability of the atmosphere. Atmospheric stability strongly influences the dispersion of emissions into the atmosphere and is therefore an important input into air quality models.

2. Methods

The methods followed for collection of temperature data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussions

Table 2-17 presents a summary of monthly, seasonal and annual temperature statistics for the current year for each of the three monitoring sites on the tract (10-m level). The temperature statistics presented for each site include means, average daily maxima, average daily minima, absolute maxima, and absolute minima.

The monthly mean temperatures for the three sites are very similar, with Site 3 slightly lower during the fall and winter months. The mean annual temperatures were 6.0 C at Site 1, 6.4 C at Site 2, and 5.0 C at Site 3.

Absolute maximum temperatures and absolute minimum temperatures at Site 1 and Site 2 were very similar. At Site 3, the absolute maximum and minimum temperatures were more extreme than at Sites 1 and 2. The extreme temperatures recorded at the tract during the current year were 31.2 and -29.6 C, both recorded at Site 3. Similarly, the average daily maximum and minimum temperatures at Site 3 were more extreme than those at Site 1 and Site 2.

The greater temperature range at Site 3 may be explained by examining the differences in site topography. Typically, evening and late night conditions in the area are characterized by clear skies and light winds, resulting in strong radiational cooling at the higher elevations and subsequent drainage of the cold, dense air to lower elevations by way of the extensive gulch network. Site 3, situated in a valley, receives this cold air drainage flow from the higher elevations to the West. Sites 1 and 2 are on locally high terrain so that the cold air drains away. These downvalley drainage flows can be deduced from an examination of the meteorological data at Site 3. Due to this local circulation, Site 3 exhibits the coldest temperatures of the three sites by sunrise. During the daytime, Site 3 reaches warmer maximum temperatures than

Table 2-17 Monthly, Seasonal, and Annual Summary of Temperatures (°C) (Mean, Average Daily Maximum, Average Daily Minimum, Absolute Maximum, Absolute Minimum) December 1978 - November 1979, 10-m Level of Site 1, Site 2 and Site 3, RBOSC Tract C-a

	Site 1					Site 2					Site 3				
Period	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min	Mean	Avg Daily Max	Avg Daily Min	Abs Max	Abs Min
Monthly															
December	- 7.5	- 4.3	-11.3	2	-24	- 6.9	- 3.6	-11.1	- 3	-24	- 9.1	- 2.3	-15.6	4	-27
January	- 8.9	- 5.9	-12.2	1	-25	- 8.5	- 4.8	-12.4	2	-26	-10	- 4.3	-17.0	3	-30
February	- 3.4	- 0.5	- 6.1	7	-14	- 2.9	0.2	- 5.8	7	-15	- 4.3	1.9	-10.6	10	-22
March	- 0.6	2.4	- 3.5	7	-10	- 0.1	3.3	- 3.0	10	-11	- 0.7	4.8	- 6.1	9	-17
April	4.6	8.1	0.6	16	- 9	5.2	9.0	1.0	17	- 9	4.5	11.4	- 2.8	20	-12
May	9.3	13.1	5.7	21	- 2	9.6	13.5	5.6	21	- 3	9.6	15.4	3.5	23	- 5
June	16.9	20.7	12.5	29	0	17	21.1	12.7	29	0	16	22.9	6.7	31	- 1
July	20.6	25.1	15.8	28	10	21	25.5	15.8	28	10	19	27.4	10.0	31	6
August	17.6	21.4	13.7	27	9	18	21.9	13.8	28	9	16	23.6	8.8	30	6
September	17.8	22.0	13.3	27	3	18	22.5	13.2	27	3	15.7	24.7	5.8	30	1
October	7.9	11.5	4.0	22	-10	8.4	12.0	4.1	22	-10	6.5	14.1	- 1.1	24	-15
November	- 2.5	- 0.1	- 5.7	9	-15	- 2.3	1.0	-60	11	-18	- 4.1	2.0	-10.1	11	-23
Seasonal															
Winter (Dec, Jan, Feb)	- 6.6	- 3.7	-10.0	7	- 2.5	- 6.1	- 2.8	9.9	7	-26	- 7.8	- 1.7	-14.6	10	-30
Spring (Mar, Apr, May)	4.4	7.9	0.9	21	-10	4.9	8.7	1.3	21	-11	4.46	10.5	- 1.8	23	-17
Summer (Jun, July, Aug)	18	22.7	14.2	29	0	18.7	23.1	14.3	29	0	17	24.9	8.7	31	- 1
Fall (Sept, Oct, Nov)	7.7	11.1	3.9	27	-15	8	11.9	3.8	27	-18	6	13.71	- 1.7	30	-23
Annual	6.0	9.1	1.9	29	-25	6.4	9.8	2.0	29	-26	5.0	11.4	- 2.7	31	-30

Site 1 or Site 2 because of its lower elevation and strong surface heating in the gulch.

The temperature record allows the calculation of the length of the frost-free period at each site. This information is helpful in determining the required hardiness and suitability of plants that will be used in revegetation of the tract. However, it should be noted that these temperatures are measured at 10 m above ground level, so that the first and last excursion below 0 C at 10 m (as used here) probably represents a "hard frost" at the ground surface. During the current year, Sites 1 and 2 had identical frost-free periods of 133 days (June 9-October 20). Site 3, subject to the effects of cold air drainage, had a considerably shorter frost-free period of 105 days (June 1-September 14). The frost-free periods were longer during 1978-79 than in 1977-78 (133 vs. 111 days at Sites 1 and 2, 105 vs. 75 days at Site 3), primarily because of a warm, dry fall. The data from Sites 1 and 2 are probably more representative of temperatures and frost-free periods over most of the tract.

Table 2-18 provides a summary of annual absolute minimum, absolute maximum, and mean values of the air temperature recorded on-site during each of the baseline years, the first MDP year, the current year, as well as the four data years combined. The four-year temperature record shows that the first year of the MDP had somewhat higher temperatures compared to the other years of record.

Stability classification (A-G), based upon temperature differences (ΔT) within a short vertical distance of the surface, are based on those in the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). The most turbulent and unstable conditions are characterized by A stability, and the least turbulent and most stable conditions are characterized by G stability.

Table 2-19 presents the diurnal distribution of atmospheric stability classes for Site 1 based on data from the current year. The stable classes (E, F, and G) occur primarily during the nighttime hours and the unstable classes (A, B, and C) occur primarily during the daytime hours when maximum solar heating of the ground surface takes place. These results are similar to those obtained during the previous year, except that there were fewer occurrences of stability class A and more of class D.

Table 2-18. Summary of Annual and Combined Four-Year Onsite Climatology of Absolute Minimum, Absolute Maximum and Mean Values of Temperature (C) During the Baseline and MDP Periods, Tract C-a

Temperatures[1/]	February 1975-January 1976	February 1976-January 1977	December 1977-November 1978	December 1978 - November 1979	Entire 4-Year Period
Site 1 (10m level)					
Absolute Minimum	- 21.1	- 21.7	- 14.5	- 24.6	- 24.6
Absolute Maximum	30.1	29.7	30.4	28.5	30.4
Mean	6.1	7.2	7.6	6.0	6.7
Site 2 (10m level)					
Absolute Minimum	- 21.4	- 22.2	- 16.1	- 26.3	- 21.4
Absolute Maximum	27.5	29.4	30.5	28.9	30.5
Mean	5.5	6.9	7.9	6.4	6.7
Site 3 (10m level)					
Absolute Minimum	- 28.2	- 25.3	- 23.1	- 29.6	- 29.6
Absolute Maximum	29.0	32.1	32.4	31.2	32.4
Mean	4.3	5.7	6.7	5.0	5.4

[1/] Minimum and maximum annual temperatures are based on hourly values for each 1-year period

Table 2-19. Stability Class Occurrence by Hour of Day, December 1978 - November 1979, Site 1, Tract C-a

	STABILITY INDEX									
HR. OF DAY	A	B	C	D	E	F	G	TOTAL	FG	EFG
1	0	0	0	41	224	52	1	318	53	277
2	0	0	0	37	217	62	2	318	64	281
3	0	0	0	40	221	55	2	318	57	278
4	0	0	0	36	217	64	1	318	65	282
5	0	0	0	42	209	61	5	317	66	275
6	0	0	0	40	226	46	3	315	49	275
7	0	0	0	98	198	18	1	315	19	217
8	0	3	7	169	118	17	2	316	19	137
9	9	15	20	177	84	10	0	315	10	94
10	32	22	32	170	54	5	0	315	5	59
11	44	32	34	166	36	4	0	316	4	40
12	63	30	28	160	30	3	0	314	3	33
13	66	30	29	153	34	4	0	316	4	38
14	58	21	36	171	33	0	0	319	0	33
15	37	39	22	181	38	0	0	317	0	38
16	13	29	29	195	53	1	0	320	1	54
17	0	2	13	200	103	2	0	320	2	105
18	0	1	0	130	181	8	0	320	8	189
19	0	0	0	44	247	26	3	320	29	276
20	0	0	0	38	211	69	3	321	72	283
21	0	0	0	40	220	55	5	320	60	280
22	0	0	0	40	213	63	4	320	67	280
23	0	0	0	40	213	63	4	320	67	280
24	0	0	0	43	204	70	2	319	72	276
ALL	322	224	250	2451	3584	758	38	7627	796	4380

Table 2-20 presents the frequency distribution of stability classes by month and season for Site 1, based on data from the current year. Unstable (classes A, B and C) conditions occurred predominantly during the summer. The occurrence of stable conditions showed less seasonal dependence.

Appendix 2-2.3 presents annual stability distribution information in the form of joint frequency distributions (JFD's) by stability class for the 10-m level wind speed and wind direction.

B. Dewpoint

1. Objectives

Dewpoint data, collected since late July 1978, is used in the evaluation of potential cooling system alternatives. The data are more directly useable than relative humidity data, which had been collected onsite for the same purposes during the baseline period and from December 1977 to late July 1978. Relative humidity can be determined from concurrent dewpoint and temperature measurements.

2. Methods

The methods followed for collection of temperature data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

3. Results and Discussion

Table 2-21 presents a summary of onsite values of dewpoint temperature, relative humidity and absolute humidity for the current year. Comparisons to the baseline years can be made for relative humidity data only. The mean annual relative humidity during the two baseline years was 36 and 31 percent, as compared to 34 percent during the first MDP year and 50 percent during the current year. The dewpoint instrument was not installed until July 1978, so the mean relative humidity given for 1977-78 may be low due to a biased data set. The range of dewpoints for the current year was -30 C to +12 C.

Table 2-20. Monthly, Seasonal, and Annual Occurrence of Stability Classes, December 1978 - November 1979, Site 1, Tract C-a

	STABILITY INDEX									
PERIOD	A	B	C	D	E	F	G	TOTAL	FG	EFG
JAN	0	0	2	298	396	45	3	744	48	444
FEB	0	2	3	200	382	25	0	612	25	407
MAR	0	2	5	251	337	34	0	629	34	371
APR	29	22	26	190	247	54	1	589	55	302
MAY	12	26	26	174	319	42	0	599	42	361
JUN	18	27	43	171	174	63	3	499	66	240
JUL	77	50	51	161	249	118	7	713	125	374
AUG	55	28	31	137	228	65	2	546	67	295
SEP	88	47	39	125	274	138	9	720	147	421
OCT	23	20	22	219	231	62	2	579	64	295
NOV	0	0	2	218	387	55	0	662	55	442
DEC	0	0	0	307	360	57	11	735	68	428
SPRING	61	50	57	615	903	130	1	1817	131	1034
SUMMER	150	105	125	469	651	246	12	1758	258	909
FALL	111	67	63	562	892	255	11	1961	266	1158
WINTER	0	2	5	805	1138	127	14	2091	141	1279
ANNUAL	322	224	250	2451	3584	758	38	7627	796	4380

Table 2-21. Monthly, Seasonal, and Annual Summary of Dewpoint, Relative Humidity and Absolute Humidity (Mean, Absolute Maximum, Absolute Minimum) for the Period December 1978 - November 1979, Tract C-a

	Dewpoint (^{0}C)			Relative Humidity (%)			Absolute Humidity (gms/m^{3})		
Monthly	Mean	Abs Max	Abs Min	Mean	Abs Max	Abs Min	Mean	Abs Max	Abs Min
December	-13	1	-27	66	100	19	1	5	1
January	-13	-1	-30	69	100	31	1	5	*
February	-10	-2	-22	60	100	22	2	4	1
March	-6	1	-16	64	100	23	3	5	1
April	-7	1	-22	47	100	19	2	5	1
May	0	9	-11	54	100	19	4	8	2
June	-2	8	-15	29	100	19	3	8	1
July	1	12	-10	31	87	19	5	11	2
August	1	11	-7	37	92	19	5	10	3
September	-2	7	-16	27	79	19	3	8	1
October	-4	4	-15	46	100	19	3	6	2
November	-10	-1	-25	59	99	19	2	5	1
Seasonal									
Winter (Dec, Jan, Feb)	-12	1	-30	65	100	19	2	5	*
Spring, (Mar, Apr, May	-5	9	-22	55	100	19	3	8	1
Summer (Jun, Jul, Aug)	0	12	-15	32	100	19	4	11	1
Fall (Sept, Oct, Nov)	-5	7	-25	43	100	19	3	8	1
Annual	-6	12	-30	50	100	19	3	11	*

*Less than 0,5

C. Wind Speed and Wind Direction

1. Objectives

The wind speed and wind direction influence atmospheric dispersion. Measurement of the frequency of occurrence of wind speed and wind direction classes can be used in interpreting air quality data.

2. Methods

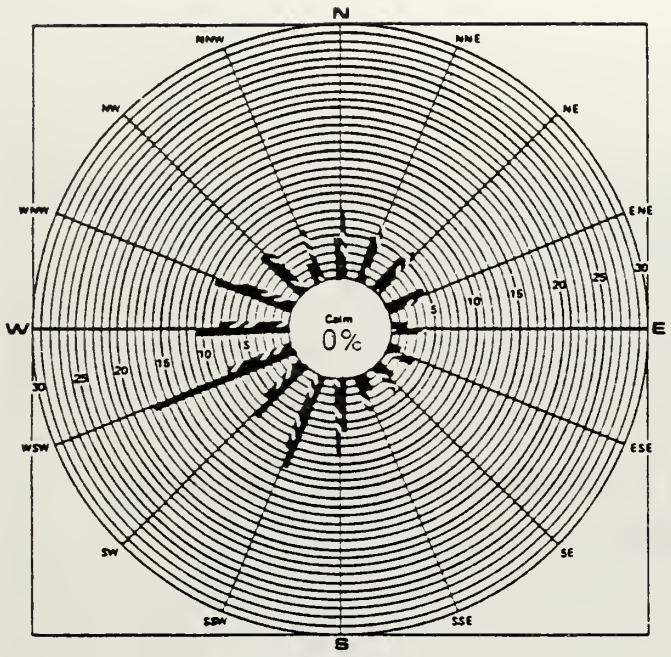
The methods followed for collection of wind data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

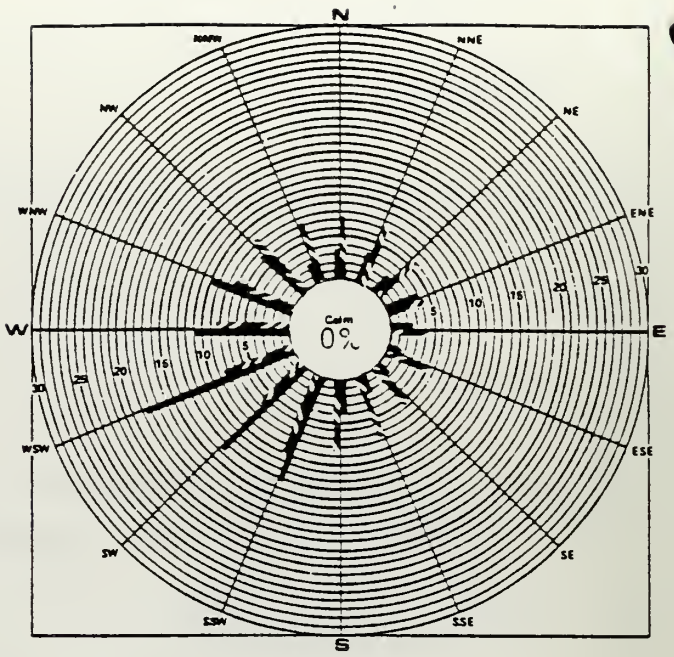
Seasonal and annual wind roses for each of the three sites for the current year are presented in Figures 2-18 to 2-25.

The Site 1 annual 10-m level wind rose for 1978-79 shows the prevalent wind direction to be from the west-southwest, with secondary maxima from the south-southwest, and southwest, and the west. The mean wind speeds associated with these directions were 8.7 mph, 9.1 mph, 6.3 mph, and 8.3 mph, respectively. These data compare well with the two annual wind roses during the baseline and the annual wind rose for the first MDP year for the 10-m level at Site 1, which also show the prevalent wind direction to be from the west-southwest. The least favored quadrant at Site 1 for wind direction, as well as the lowest annual average wind speeds, was the southeast quadrant during all four years. The north and the north-northeast were directions of secondary wind speed maxima at Site 1 during the four-year period.

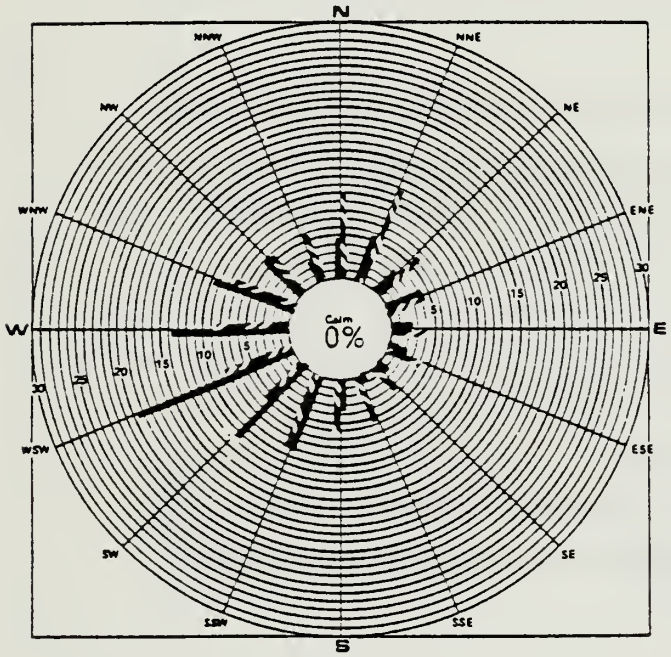
The Site 2 annual 10-m level wind rose for the current year shows the prevalent wind direction to be from the southwest, with secondary maxima from the west and from the west-southwest. The mean wind speeds associated with these directions were 12.5 mph, 7.7 mph, and 9.5 mph, respectively. These data compare favorably with the two annual wind roses from the baseline period and the annual wind



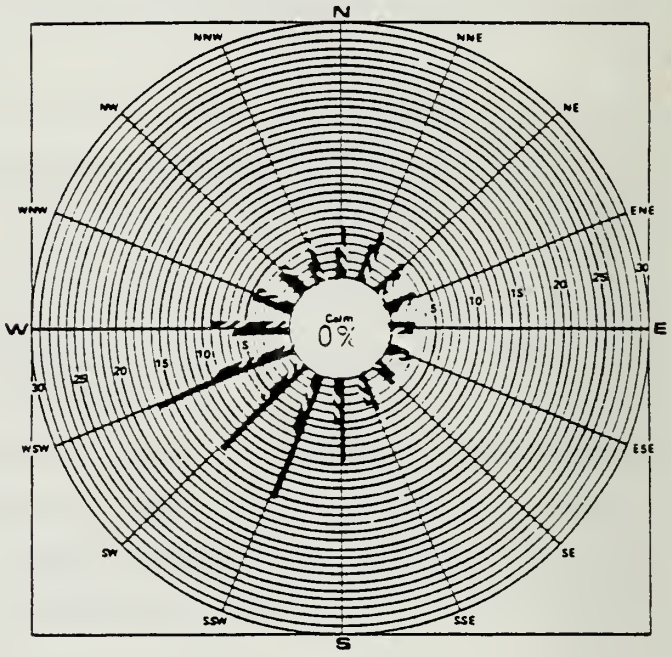
Spring



Summer



Autumn



Winter

WIND DIRECTION (%)
WIND SPEED (MPH)

Figure 2-18. Seasonal Wind Roses, Dec 1978-Nov 1979, Site 1 10 m Level, Tract C-a

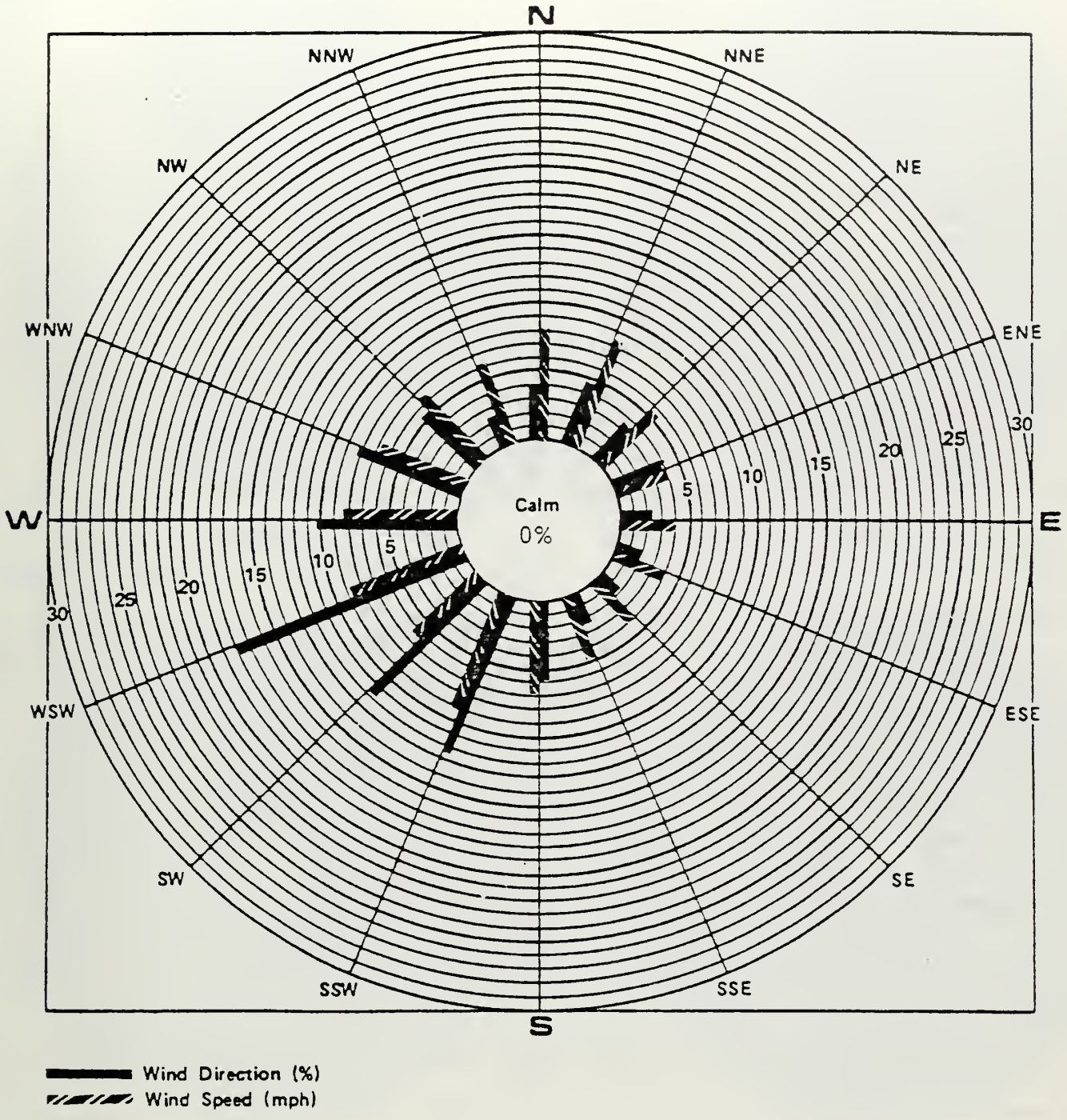


Figure 2-19. Annual Wind Rose, Dec 1978-Nov 1979, Site 1 10 m Level, Tract C-a

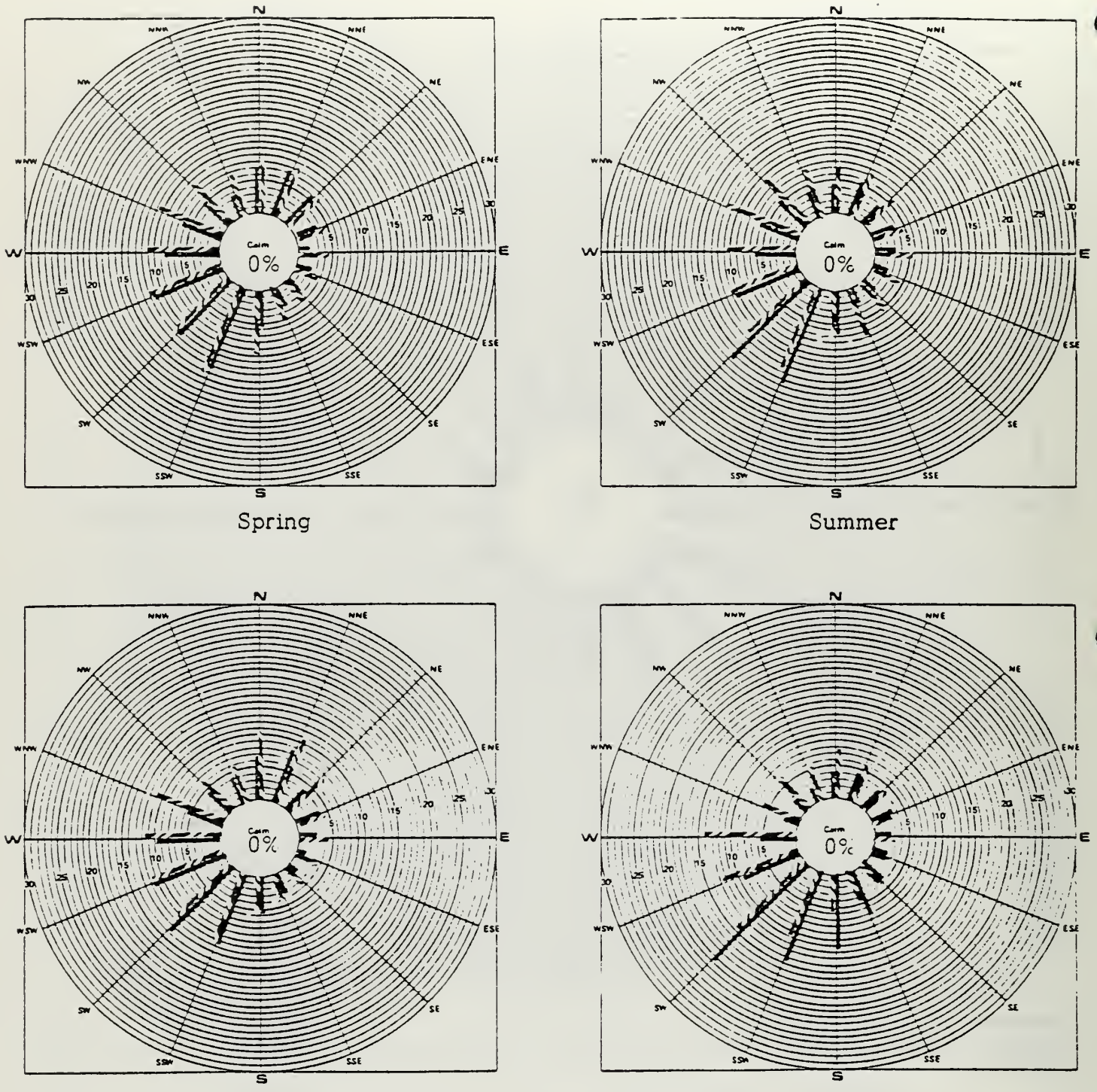


Figure 2-20. Seasonal Wind Roses, Dec 1978-Nov 1979, Site 1 60 m Level, Tract C-a

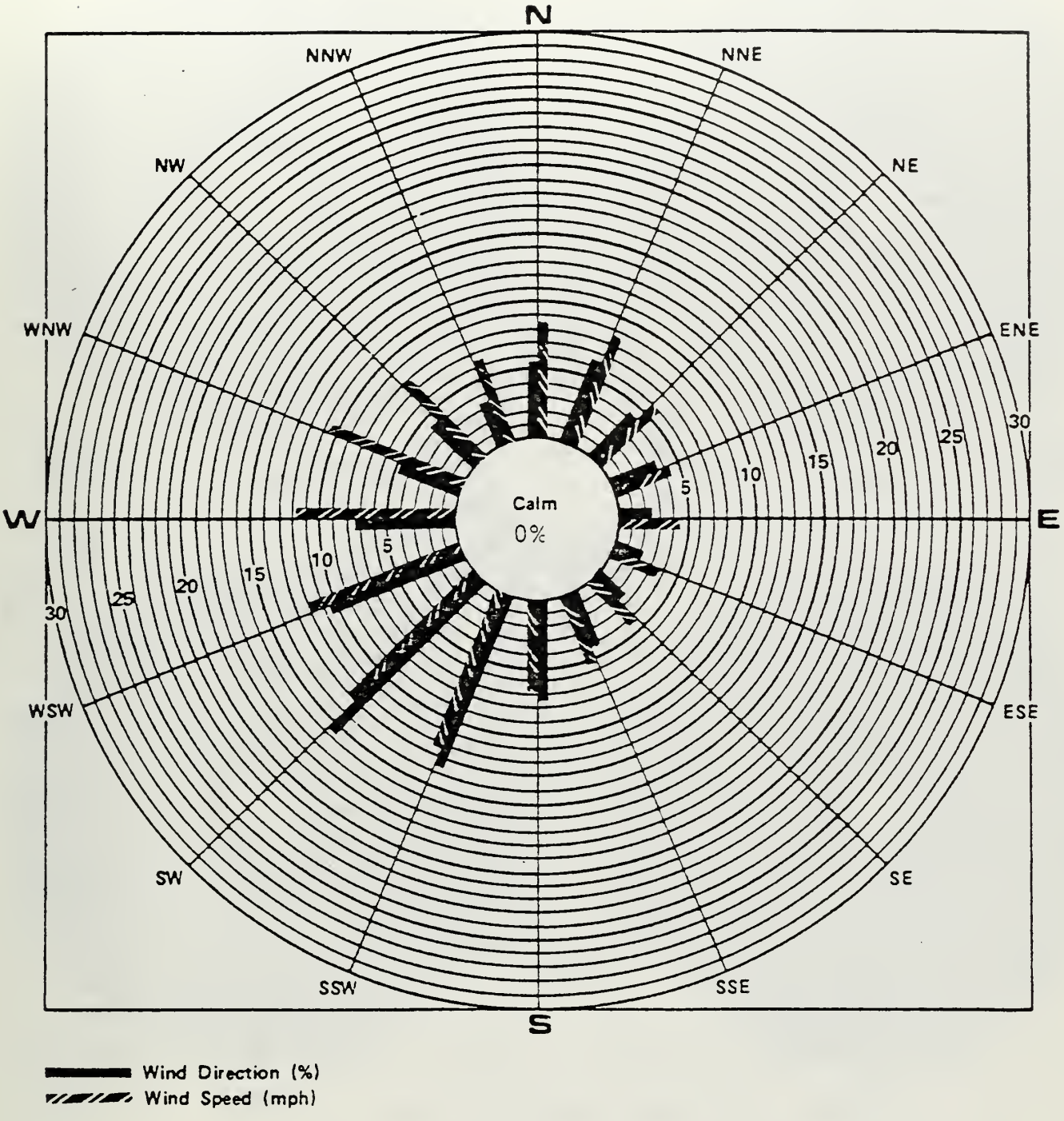
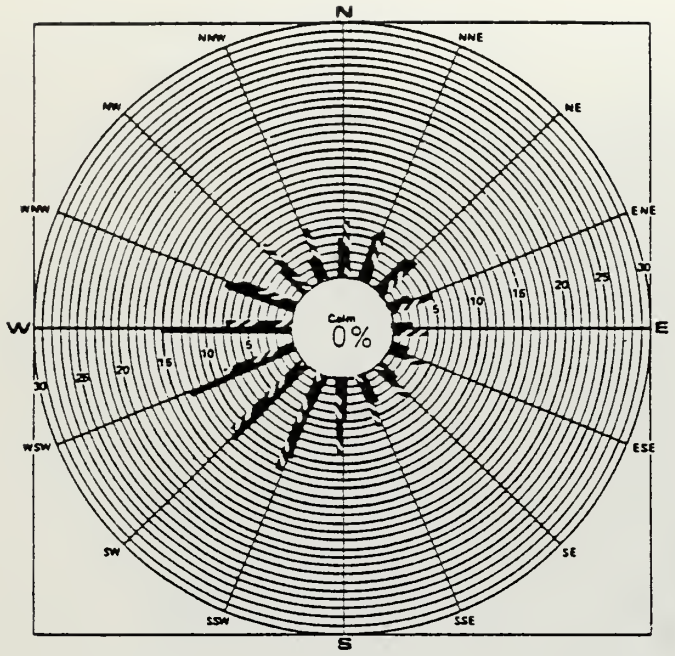
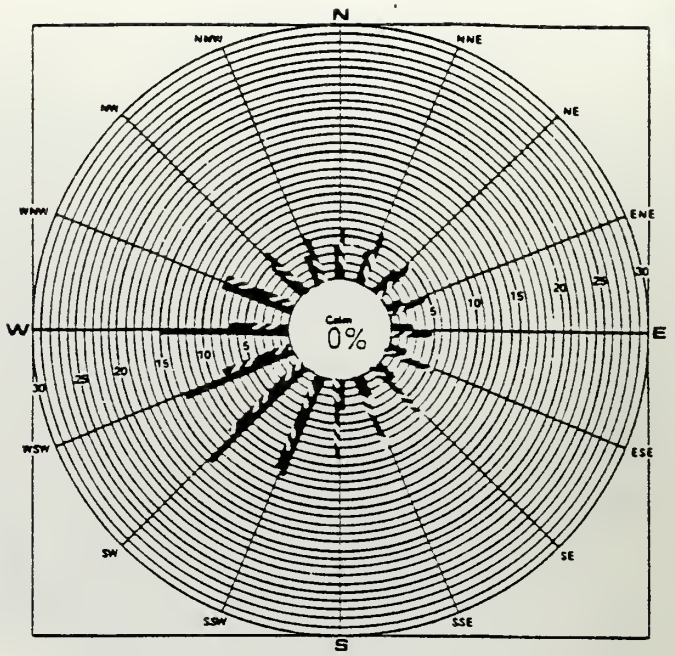


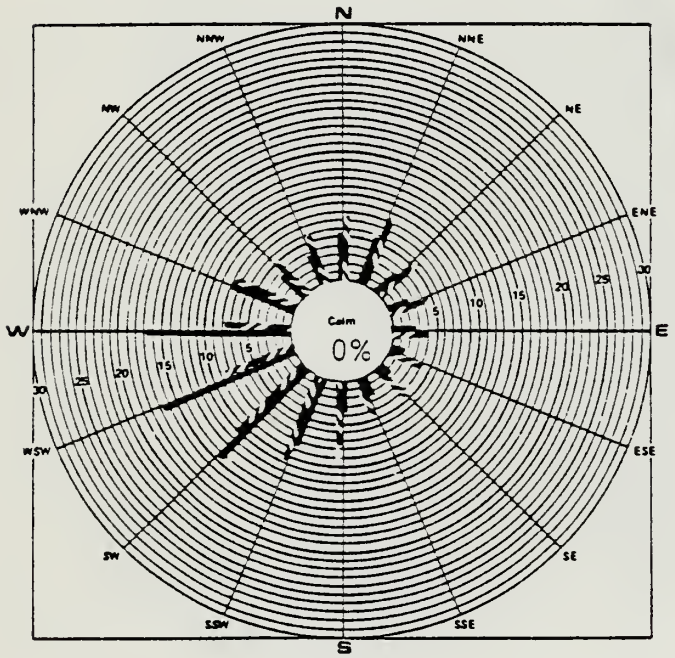
Figure 2-21. Annual Wind Rose, Dec 1978-Nov 1979, Site 1 60 m Level, Tract C-a



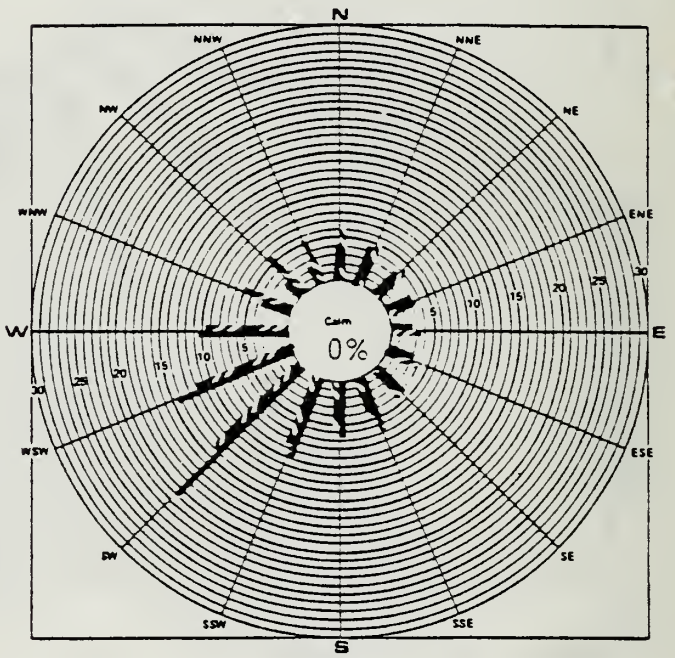
Spring



Summer



Autumn



Winter

WIND DIRECTION (%)
WIND SPEED (MPH)

Figure 2-22. Seasonal Wind Roses, Dec 1978-Nov 1979, Site 2 10 m Level, Tract C-a

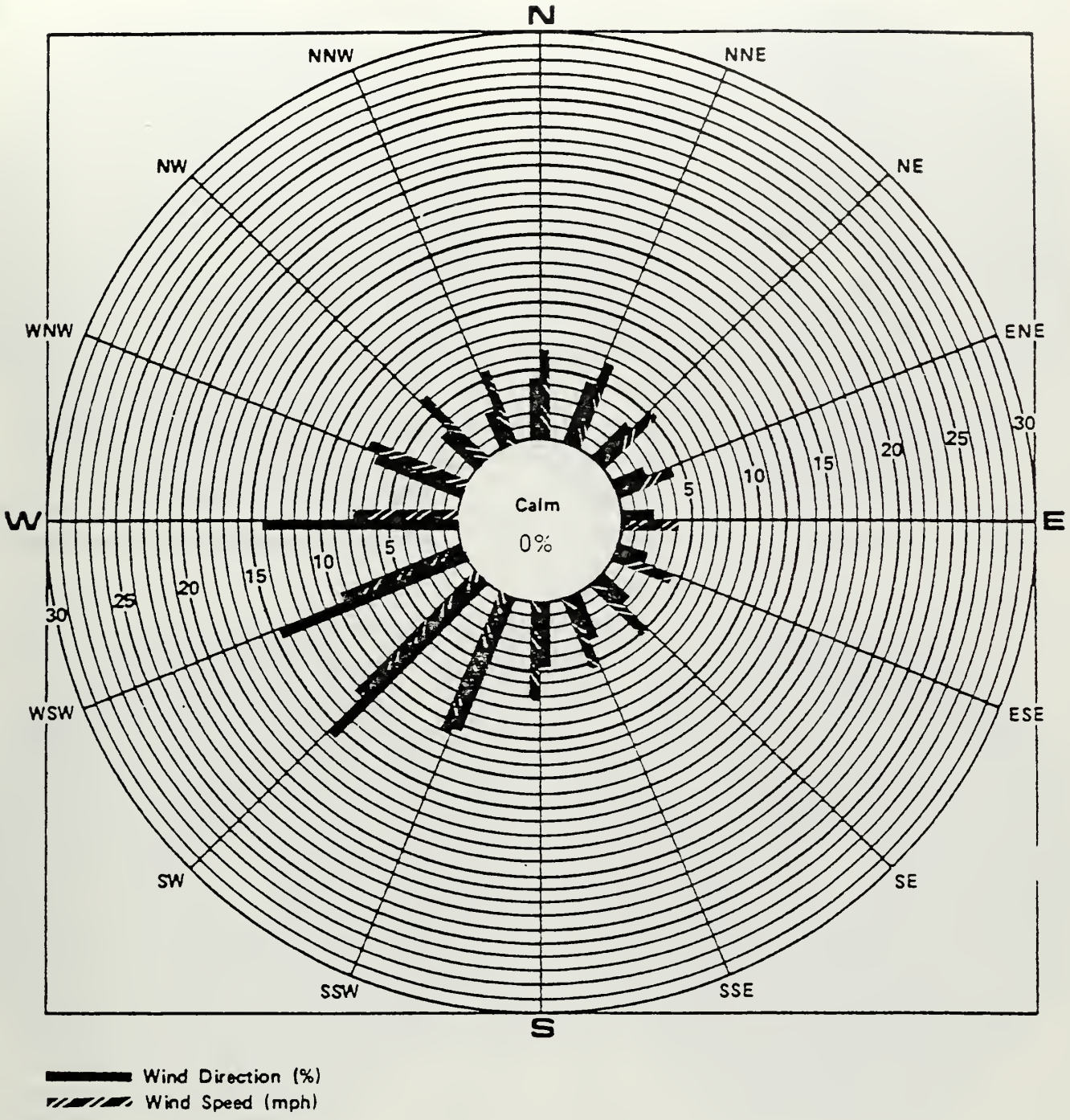


Figure 2-23. Annual Wind Rose, Dec 1978-Nov 1979, Site 2 10 m Level, Tract C-a

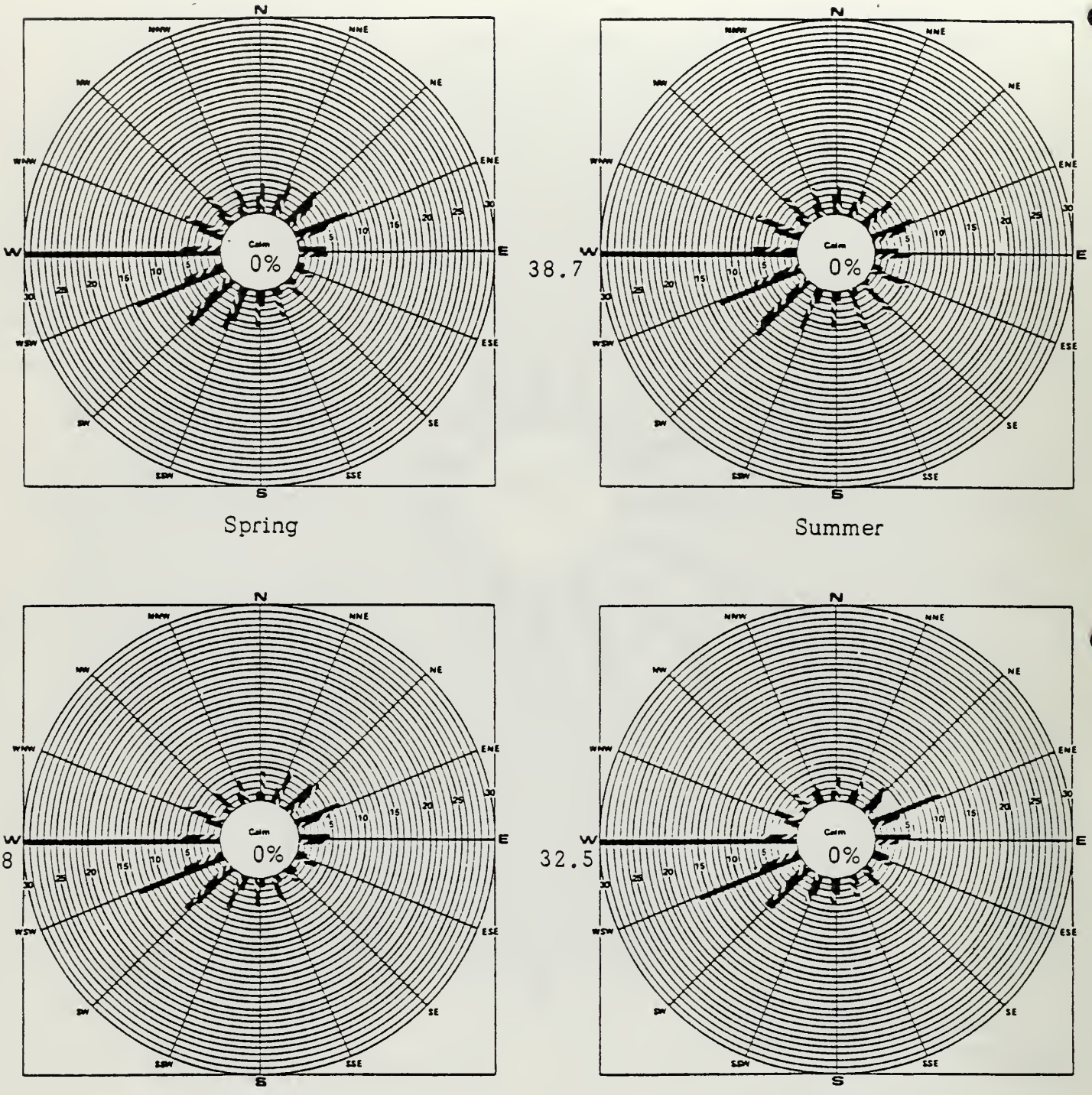


Figure 2-24. Seasonal Wind Roses, Dec 1978-Nov 1979, Site 3 10 m Level, Tract C-a

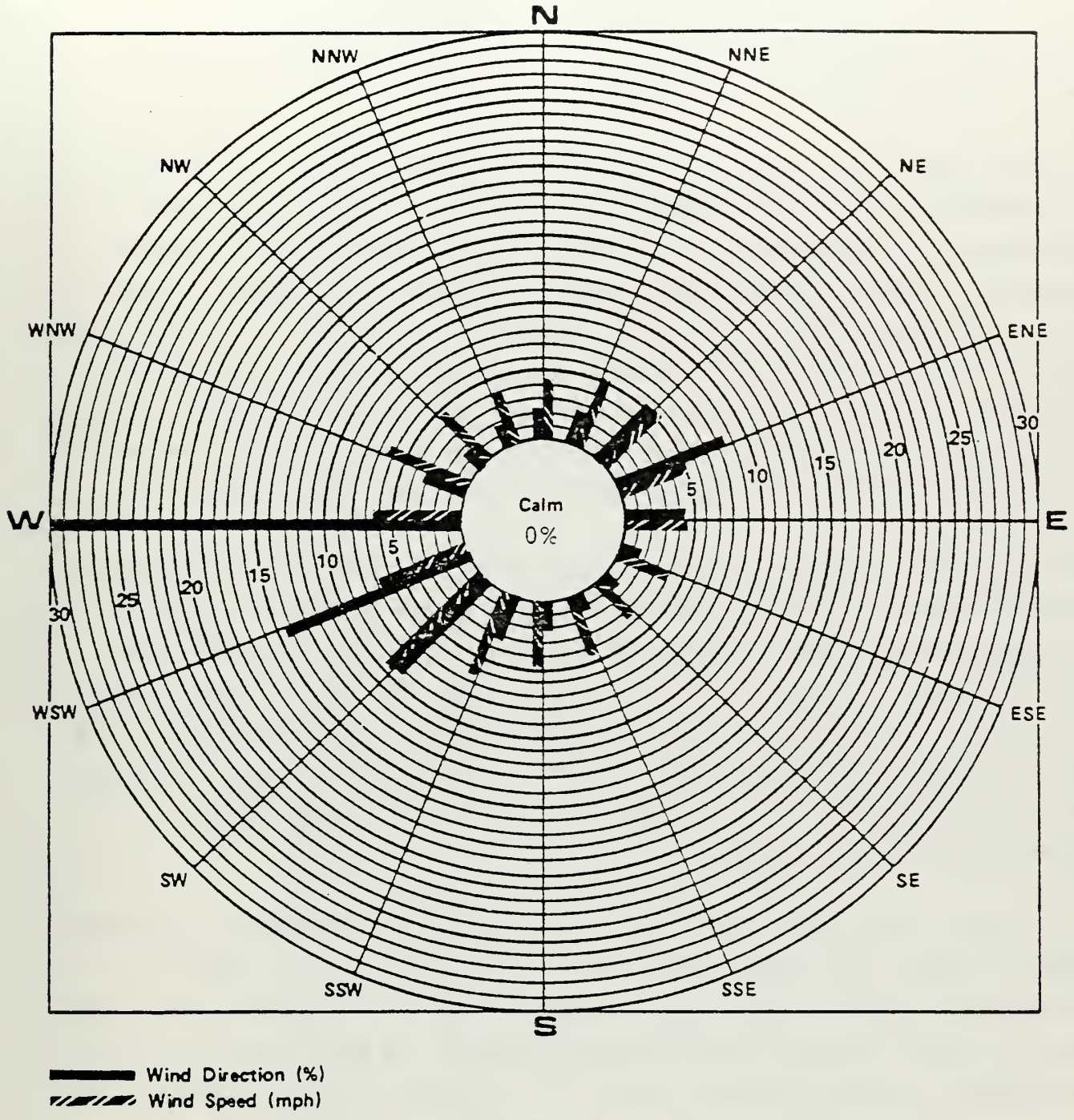


Figure 2-25. Annual Wind Rose, Dec 1978-Nov 1979, Site 3 10 m Level, Tract C-a

rose from 1977-78 at Site 2, which also show the prevalent wind directions to be from the west and southwest. The least favored wind directions and the lowest annual average wind speeds are in the southeast quadrant at Site 2, similar to conditions found at Site 1.

The Site 3 annual 10-m level wind rose for the current year shows the prevalent wind direction, by far, to be from the west (35.9 percent of total annual occurrences), with secondary maxima from the west-southwest and the southwest. The mean wind speeds associated with these directions were 6.5 mph, 6.8 mph, and 9.5 mph, respectively. These data are similar to the previous three years of record, which also show the prevalent wind direction to be from the west (36.1 and 28.5 percent of the total annual occurrences for the baseline period and 35.8 percent for 1977-78). The high frequency of west winds is the result of the general westerly circulation combined with nighttime drainage winds.

Table 2-22 shows a summary of the absolute maximum and mean hourly wind speeds recorded at each of the three sites during each of the data years. The mean wind speeds for the three sites during the current year are 7.3 mph at the Site 1 10-m level, 9.6 mph at the Site 1 60-m level, 8.4 mph at Site 2 and 6.2 mph at Site 3. As shown in Table 2-22, there has been little variation in the mean wind speed during the period of record. The decrease in mean wind speeds from Site 2 (highest) to Site 3 (lowest) reflects the relative degree of sheltering by the local terrain.

Tables 2-23 to 2-26 present the annual frequency of wind direction occurrences by hour for each of the three sites (including the 60-m level at Site 1) during the current year. These tables show the same data as given in the wind roses, but also illustrate the variation throughout the day. Each site shows the dominance of westerly winds. The Site 3 winds show the most extreme case, where winds from the 22.5° west sector occurred more than 60 percent of the time in the early morning hours. These winds are associated with downvalley drainage flows, as discussed earlier.

The most noteworthy event evident in Tables 2-23 to 2-26 is the diurnal variation in the wind direction. It is to be expected that the downvalley wind at Site

Table 2-22. Summary of Annual Absolute Maximum and Mean Values of Wind Speed (MPH) at Tract C-a During Baseline Period (February 1975-January 1976, February 1976-January 1977) and the MDP Period (December 1977-November 1978, December 1978-November 1979)

	Maximum[1/]				Mean				Four-Year Combined Mean
	1975-1976	1976-1977	1977-1978	1978-1979	1975-1976	1976-1977	1977-1978	1978-1979	
Site 1									
10m Wind Speed	30.8	32.3	30.0	27.5	7.7	7.2	7.6	7.3	7.5
60 m Wind Speed	43.0	56.6	41.5	36.8	10.6	10.0	10.6	9.6	10.2
Site 2									
10m Wind Speed	36.7	39.2	39.0	36.1	9.1	8.4	9.2	8.4	8.8
Site 3									
10m Wind Speed	29.9	26.4	26.0	24.5	6.6	6.9	6.7	6.2	6.6

[1/] Hourly values for this period

Table 2-23. Wind Direction Frequency by Hour of Day, December 1978 - November 1979, 10m Level at Site 1, Tract C-a

	WIND DIRECTION																	
HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	4.3	3.4	2.5	0.6	0.3	1.5	1.9	2.2	4.3	10.5	12.7	25.7	11.8	10.2	6.5	1.5	0.0	100.
2	4.6	3.4	1.5	1.9	0.9	0.6	1.9	2.3	6.2	10.2	10.2	25.4	11.1	11.1	6.5	1.9	0.3	100.
3	5.0	4.6	1.2	0.9	0.9	0.6	3.4	3.4	5.0	8.4	13.0	21.7	12.7	11.5	5.3	2.5	0.0	100.
4	2.5	3.1	1.9	2.5	0.9	1.5	1.2	2.8	4.6	8.7	12.7	22.9	9.9	13.9	7.7	2.5	0.6	100.
5	2.5	3.7	2.3	1.2	1.6	0.3	2.2	2.5	3.1	9.9	16.5	21.4	10.9	12.1	6.2	2.8	0.3	100.
6	1.9	4.7	3.7	1.9	1.2	0.9	2.2	3.1	8.7	8.1	14.3	22.4	10.3	7.8	5.3	3.4	0.0	100.
7	4.4	7.2	2.8	7.2	2.2	3.7	2.2	5.3	5.9	10.3	10.9	16.8	6.9	7.5	4.4	2.5	0.0	100.
8	4.0	4.0	5.9	11.5	5.9	6.5	5.0	4.7	9.0	11.2	9.7	9.7	4.4	4.0	2.5	1.2	0.6	100.
9	3.1	4.0	8.1	12.8	6.7	7.5	2.8	3.7	7.5	12.1	6.9	13.1	4.0	1.6	2.8	1.2	0.0	100.
10	4.0	6.2	6.2	11.8	7.5	3.4	4.0	4.0	8.4	11.2	5.6	10.3	1.4	3.4	3.4	1.9	0.0	100.
11	5.3	5.3	7.8	8.7	3.7	4.1	2.8	3.7	4.7	14.1	7.5	12.5	9.1	3.4	3.7	3.4	0.0	100.
12	5.4	6.3	7.9	3.5	3.5	2.2	2.8	1.3	9.8	14.2	8.8	11.7	11.7	5.7	2.5	2.8	0.0	100.
13	2.8	7.8	5.3	4.7	4.4	1.9	0.9	1.2	5.6	17.5	8.7	14.1	9.4	6.9	5.9	2.8	0.0	100.
14	3.7	7.1	5.6	5.9	2.5	1.5	1.2	1.5	6.2	14.6	9.4	17.0	9.9	7.4	5.6	1.9	0.0	100.
15	4.4	9.0	6.5	2.5	2.8	0.3	2.2	0.9	6.5	16.5	12.1	10.6	10.6	7.8	4.4	2.8	0.0	100.
16	4.6	8.3	4.0	3.1	4.6	1.8	1.2	2.5	9.0	20.0	9.0	10.5	6.9	5.8	5.2	3.4	0.0	100.
17	5.8	4.9	4.0	4.0	1.7	2.8	0.6	3.1	8.0	19.1	11.4	9.5	6.8	7.1	8.0	3.7	0.0	100.
18	3.1	4.6	3.7	4.0	0.6	0.6	1.5	3.4	5.8	19.7	11.1	15.7	9.8	5.5	7.1	3.4	0.3	100.
19	4.0	4.3	1.5	1.5	0.9	1.9	1.2	1.2	5.2	10.5	23.1	16.7	10.5	8.0	6.8	2.5	0.0	100.
20	3.4	2.2	2.2	0.6	0.0	1.5	1.2	0.9	2.5	11.7	14.8	26.8	10.2	13.2	6.5	2.2	0.3	100.
21	4.0	3.1	1.5	0.6	0.6	0.9	0.9	2.5	4.6	8.6	14.8	25.0	13.0	11.1	6.2	2.5	0.0	100.
22	3.7	4.0	1.2	0.9	1.9	0.6	1.2	2.2	5.9	9.0	12.7	22.8	14.8	11.1	5.9	2.2	0.0	100.
23	5.2	3.1	1.2	0.3	1.2	0.9	1.2	1.2	4.0	8.6	13.6	23.1	16.7	9.9	5.6	3.7	0.3	100.
24	4.0	3.7	1.9	2.5	0.9	1.2	1.5	2.2	2.5	10.8	13.9	23.2	13.0	11.5	4.3	2.8	0.0	100.
ALL	4.0	4.9	3.8	4.0	2.5	2.0	2.0	2.6	5.9	12.3	11.7	17.9	10.2	8.2	5.3	2.6	0.1	100.

NUMBER OF OBS = 7739

Table 2-24. Wind Direction Frequency by Hour of Day, December 1978 - November 1979, 60m Level at Site 1, Tract C-a

	WIND DIRECTION																	
HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	6.8	9.0	4.3	1.2	1.2	1.9	2.5	5.6	9.3	9.0	17.3	11.1	6.0	3.7	4.0	5.9	0.0	100.
2	9.6	6.8	3.7	1.9	0.9	1.9	2.8	6.2	7.7	9.9	17.0	9.9	6.8	6.5	2.8	5.6	0.0	100.
3	7.7	7.7	4.6	1.5	1.2	1.5	2.5	3.1	12.4	11.5	14.6	12.1	6.8	3.4	2.8	6.2	0.3	100.
4	8.7	6.8	4.3	3.4	2.2	0.6	0.6	4.6	9.6	12.4	15.2	11.5	6.5	3.1	4.6	5.6	0.3	100.
5	7.1	6.8	3.7	2.2	0.9	1.9	2.8	2.8	10.2	11.2	16.5	10.9	6.5	4.3	5.3	6.5	0.3	100.
6	6.5	6.2	4.0	2.8	1.6	1.6	5.3	4.9	12.1	8.7	15.6	11.6	7.5	4.7	3.1	4.0	0.3	100.
7	4.7	6.9	6.9	4.0	2.2	5.0	4.0	8.4	8.4	10.3	15.9	8.4	5.3	2.8	3.7	2.8	0.3	100.
8	2.5	5.9	6.5	9.0	4.4	5.6	5.9	6.5	10.6	11.8	13.4	9.3	3.4	2.2	1.2	1.6	0.0	100.
9	3.7	5.3	4.4	11.8	7.5	6.2	5.6	5.9	8.4	10.9	10.6	12.1	2.9	1.2	2.2	1.2	0.0	100.
10	4.0	4.7	6.2	6.9	9.0	4.0	4.0	7.8	5.6	13.1	12.5	10.9	6.3	2.5	1.6	0.9	0.0	100.
11	3.7	5.9	5.3	6.3	5.3	2.2	3.7	5.9	4.7	14.7	13.7	12.2	7.2	4.1	3.1	1.9	0.0	100.
12	3.5	6.0	5.7	4.7	2.8	1.9	2.5	3.5	4.7	18.3	15.1	11.0	9.1	4.7	4.7	1.6	0.0	100.
13	3.1	5.6	5.9	2.8	3.4	2.5	2.5	1.6	3.4	17.5	17.8	9.7	9.1	6.9	5.6	2.5	0.0	100.
14	4.0	6.6	3.1	6.2	2.8	1.2	0.9	2.2	5.0	13.0	18.6	12.1	9.9	7.7	4.3	2.2	0.0	100.
15	3.4	7.8	5.0	2.8	3.4	1.2	2.5	1.6	4.4	17.1	15.9	10.0	10.9	6.5	4.4	3.1	0.0	100.
16	4.0	8.3	4.6	4.3	2.2	1.5	1.2	1.8	6.8	18.8	14.5	8.0	8.3	7.1	5.5	3.1	0.0	100.
17	4.0	6.5	4.6	4.0	3.1	0.6	2.8	3.4	5.2	21.0	12.0	8.3	7.1	8.3	6.5	2.5	0.0	100.
18	4.6	6.6	3.1	4.0	1.2	1.8	1.5	5.8	5.2	19.8	14.5	10.2	6.8	6.2	4.9	4.0	0.3	100.
19	4.6	7.4	3.1	1.2	1.2	1.2	2.8	2.5	7.1	16.9	19.4	9.5	8.6	4.9	6.5	3.1	0.0	100.
20	7.1	6.4	1.8	2.5	0.9	0.3	2.5	1.6	5.1	17.5	20.9	8.0	7.7	5.8	5.5	4.3	0.3	100.
21	6.5	5.5	4.6	0.3	0.9	0.9	1.5	4.6	8.6	13.5	18.5	10.2	7.1	8.0	5.8	2.8	0.6	100.
22	7.1	4.6	3.1	1.8	0.3	0.9	2.2	4.9	10.2	11.7	19.4	9.8	8.6	6.5	5.2	4.6	0.0	100.
23	7.4	9.0	2.8	0.6	1.5	1.8	1.8	2.5	7.7	12.0	15.7	15.7	10.5	3.1	4.9	4.0	0.0	100.
24	9.6	4.9	4.0	3.4	1.5	1.5	0.3	3.4	9.0	11.1	14.5	15.7	7.4	4.6	4.3	4.6	0.0	100.
ALL	5.6	6.5	4.4	3.7	2.6	2.1	2.7	4.1	7.6	13.8	15.9	10.8	7.4	5.0	4.3	3.5	0.1	100.

NUMBER OF OBS = 7744

Table 2-25. Wind Direction Frequency by Hour of Day, December 1978 - November 1979, 10m Level at Site 2, Tract C-a

HR. OF DAY	WIND DIRECTION																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	4.1	2.9	2.9	1.6	1.0	0.3	2.5	6.3	3.8	7.3	16.2	18.1	18.4	7.3	3.5	3.8	0.0	100.
2	4.8	3.2	2.9	0.6	1.0	1.3	3.2	4.1	7.9	7.3	13.7	16.5	19.7	6.7	4.1	3.2	0.0	100.
3	4.8	3.8	2.5	1.6	0.6	1.0	3.5	3.2	4.4	8.6	12.4	17.1	20.6	8.9	2.9	4.1	0.0	100.
4	3.5	4.1	2.5	2.5	1.9	1.0	2.2	4.1	5.1	8.6	15.2	15.2	21.0	7.3	2.2	3.5	0.0	100.
5	4.5	4.8	2.2	1.6	1.3	1.9	2.2	1.6	5.7	9.2	14.6	15.6	20.4	7.3	3.5	3.5	0.0	100.
6	5.1	3.8	2.9	2.9	1.0	1.3	4.1	4.8	5.1	6.7	13.1	18.5	15.0	8.0	4.1	3.5	0.3	100.
7	5.4	7.6	3.2	2.9	1.9	3.2	5.4	6.3	5.4	7.6	14.3	14.3	7.6	7.0	3.2	4.8	0.0	100.
8	5.4	6.4	5.1	3.8	8.6	5.4	5.1	5.1	7.3	8.0	13.1	11.1	6.7	3.8	1.9	3.2	0.0	100.
9	3.2	6.0	7.6	6.3	8.6	7.3	4.1	3.5	5.7	9.5	13.0	11.1	7.3	1.9	1.9	2.9	0.0	100.
10	5.7	3.8	6.0	4.7	8.8	5.7	4.7	6.0	4.4	8.9	12.6	11.0	10.7	3.5	2.5	0.9	0.0	100.
11	5.1	8.6	4.4	5.4	5.7	2.2	3.2	2.5	4.8	10.2	17.1	13.0	8.3	4.4	2.2	2.9	0.0	100.
12	4.9	6.9	2.6	4.9	3.3	2.3	2.9	2.6	5.6	13.1	13.1	15.4	9.8	7.5	2.6	2.6	0.0	100.
13	4.5	7.1	3.2	2.6	1.9	3.6	1.0	1.6	3.6	12.3	16.8	12.6	12.0	9.4	4.2	3.6	0.0	100.
14	4.5	6.1	4.8	1.6	3.8	1.9	1.3	1.6	6.4	9.6	19.6	10.6	12.5	9.6	3.5	2.6	0.0	100.
15	4.5	3.8	8.3	2.6	1.6	1.9	2.9	1.3	2.9	12.8	17.3	9.9	13.7	9.6	2.9	4.2	0.0	100.
16	5.7	5.7	6.9	3.8	1.6	1.3	2.2	2.8	4.4	11.9	18.2	10.4	9.1	8.2	4.7	3.1	0.0	100.
17	5.3	7.2	5.7	2.5	1.9	0.6	2.5	5.3	4.1	17.0	14.8	9.4	8.2	7.9	4.7	2.8	0.0	100.
18	5.3	5.0	3.7	2.2	1.2	2.5	2.5	5.9	4.7	14.1	17.2	10.6	8.7	5.9	7.2	3.1	0.0	100.
19	3.1	4.4	2.5	2.2	0.9	2.2	1.6	2.5	6.2	14.3	17.4	15.9	14.6	5.9	3.4	2.8	0.0	100.
20	2.8	3.1	1.2	1.2	1.2	1.2	2.2	2.2	3.7	13.0	22.0	15.2	15.8	9.3	4.0	1.6	0.0	100.
21	1.9	2.2	2.2	0.6	0.6	1.3	3.1	2.8	3.4	12.5	17.9	18.8	17.2	8.8	4.7	1.9	0.0	100.
22	5.3	3.4	1.3	0.9	0.9	0.3	1.9	5.0	3.4	8.2	20.7	18.2	17.9	6.3	4.7	1.6	0.0	100.
23	5.0	4.4	0.6	1.6	0.9	1.6	2.2	2.5	3.5	9.1	15.1	18.9	21.8	7.3	3.2	2.2	0.0	100.
24	5.1	2.5	3.5	1.6	0.0	1.6	1.0	1.3	4.4	9.5	15.6	20.6	21.0	5.7	3.2	3.5	0.0	100.
ALL	4.6	4.9	3.7	2.6	2.5	2.2	2.8	3.6	4.8	10.4	15.9	14.5	14.1	7.0	3.6	3.0	0.0	100.

NUMBER OF OBS = 7573

Table 2-26. Wind Direction Frequency by Hour of Day, December 1978 - November 1979, 10m Level at Site 3, Tract C-a

WIND DIRECTION

HR. OF DAY	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	CALM	TOTAL
1	2.8	1.3	2.2	3.4	1.6	1.9	1.6	0.3	0.9	1.3	3.8	16.6	58.6	1.3	0.9	0.9	0.6	100.
2	0.6	0.6	2.8	3.4	1.9	1.3	1.6	0.3	1.9	2.5	2.2	16.3	59.9	1.6	0.9	1.6	0.6	100.
3	1.9	1.9	2.8	2.5	2.2	0.6	1.6	0.6	1.3	1.6	1.9	14.2	64.2	0.9	0.6	1.3	0.0	100.
4	1.6	1.0	2.2	1.9	1.6	1.0	0.3	1.0	1.3	1.6	3.8	13.7	63.2	1.9	1.9	1.3	1.0	100.
5	0.3	1.6	3.5	2.2	2.6	0.6	0.6	0.3	0.6	2.2	4.8	13.7	63.3	1.9	0.0	1.0	0.6	100.
6	2.2	2.2	2.9	2.6	1.3	1.0	0.6	0.6	1.6	2.9	2.9	14.1	56.2	3.5	1.3	3.8	0.3	100.
7	2.2	4.1	6.1	9.9	3.5	2.2	2.5	1.0	1.3	4.1	4.8	17.8	28.7	4.5	3.2	3.5	0.6	100.
8	1.3	2.5	6.7	21.7	8.9	5.7	3.5	4.8	3.2	3.2	3.8	11.1	17.8	1.6	1.9	2.2	0.0	100.
9	4.1	1.9	8.9	21.0	14.0	2.9	2.2	3.2	5.1	3.5	8.9	10.5	6.9	1.0	1.3	1.9	0.6	100.
10	2.2	4.1	10.2	25.4	14.0	5.4	1.9	0.3	3.5	2.5	10.5	8.3	5.7	2.9	1.0	1.3	1.0	100.
11	2.8	3.8	9.5	22.1	9.5	2.8	1.9	2.2	3.2	5.7	12.6	11.0	6.0	2.2	2.8	1.6	0.3	100.
12	3.5	5.1	8.3	15.4	9.3	1.9	1.6	1.3	1.9	4.2	17.6	14.7	7.4	2.2	3.2	1.9	0.3	100.
13	3.5	5.1	8.3	14.6	4.1	1.6	0.3	0.6	1.6	5.4	21.6	12.4	12.7	3.8	2.9	1.6	0.0	100.
14	3.1	4.4	9.1	10.1	6.3	0.9	0.6	1.3	2.5	5.0	10.2	15.4	15.9	4.1	3.8	1.3	0.0	100.
15	1.9	3.7	7.5	14.7	5.3	0.9	0.9	0.9	2.8	5.6	20.6	12.2	12.8	6.9	0.6	2.5	0.0	100.
16	4.3	3.7	7.4	13.0	4.9	1.2	1.5	2.2	2.5	4.0	20.7	13.3	12.3	5.9	0.6	2.5	0.0	100.
17	1.9	3.7	7.1	7.7	2.8	2.5	1.5	3.7	3.7	6.8	19.4	15.4	11.4	6.8	3.1	2.5	0.0	100.
18	2.8	3.4	5.9	5.2	1.9	1.9	1.2	4.0	3.1	4.6	14.8	16.0	24.1	5.9	3.1	2.2	0.0	100.
19	2.8	0.9	3.4	3.4	3.1	0.9	0.9	0.3	2.5	1.9	9.0	21.9	39.8	4.6	2.2	2.5	0.0	100.
20	1.5	1.5	1.8	2.2	2.2	1.8	0.3	1.5	1.5	2.8	5.2	16.9	55.7	2.8	0.9	1.2	0.0	100.
21	0.6	1.9	2.2	2.8	3.4	1.5	0.3	0.6	1.9	2.2	4.3	15.7	57.4	2.8	1.2	0.6	0.6	100.
22	1.9	0.6	2.5	1.5	2.2	0.0	1.5	0.6	0.9	1.5	4.9	18.2	56.5	3.1	1.2	2.2	0.6	100.
23	1.9	2.5	2.5	1.2	1.5	1.9	1.2	0.6	0.3	1.5	3.7	16.7	59.8	0.9	0.3	1.9	0.9	100.
24	1.6	1.9	4.3	2.8	1.9	1.2	0.9	0.9	1.6	2.8	3.1	12.1	56.4	3.7	0.6	1.6	0.6	100.
ALL	2.2	2.6	5.3	8.7	4.5	1.8	1.3	1.4	2.1	3.3	9.3	14.5	35.7	3.2	1.6	1.9	0.4	100.

NUMBER OF OBS = 7650

3 would reverse and become an upvalley wind shortly after sunrise, due to local solar heating of the terrain. The effect becomes moderately strong and results in an upvalley flow (against the general westerly circulation) approximately 50 percent of the time during the morning hours of 0900 and 1000. Also interesting is the fact that this upvalley flow is common at all three of the sites. At the 10-m level at Sites 1 and 2 it occurs approximately 25 and 20 percent of the time, respectively. These upslope easterly winds are uncommon at other times of the day. In addition, this upslope flow appears to be fairly deep, since these easterly winds also occur approximately 20 percent of the time at 0900 hours at the 60-m level at Site 1.

D. Precipitation

1. Objectives

Precipitation is recorded to provide data on the scavenging effects of rain and snowfall on air quality. The moisture content of the ground surface may also influence wind erosion.

2. Methods

The methods followed for collection of these data were described in RBOSC MDP Report 2 and are not repeated herein.

3. Results and Discussion

Precipitation data from the several measuring methods for the period June 1978-November 1978 are included in the data appendix (Appendix 2-2.4). There is a significant difference in the reported precipitation between the gauges installed at each site, with the weighing bucket gauges in general recording relatively higher precipitation amounts than the tipping bucket gauges.

Table 2-27 presents the monthly, seasonal and annual precipitation (inches) at Sites 1, 2 and 3 for the current year. The table is compiled from data which is collected by tipping bucket gauges, weighing bucket gauges, and wedge

Table 2-27. Monthly, Seasonal, and Annual Precipitation (inches) at Sites 1, 2, and 3 from available Tipping Bucket Gauge, Weighing Bucket Gauge, and Wedge Gauge Data at Tract C-a for the period December 1978 - November 1979

	Site 1			Site 2			Site 3	
Month	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Weighing Bucket Gauge	Wedge Gauge	Tipping Bucket Gauge	Wedge Gauge
December	0.38	1.73	1.35	0.72	1.63	1.17	0.75	1.15
January	0.26	1.14	0.73	0.18	1.25	1.03	0.33	0.80
February	0.34	0.65	0.35	0.26	0.65	0.60	0.36	0.57
March	1.23	1.82	1.66	0.91	1.46	1.40	1.33	1.53
April	0.28	0.85	0.71	0.29	0.57	0.48	0.37	0.44
May	2.15	3.39	3.07	2.13	2.75	2.71	2.25	2.19
June	0.30	0.36	0.39	0.32	0.45	0.48	0.35	0.42
July	0.92[1/]	0.77	0.80	0.78	0.81	0.81	0.45	0.47
August	1.16	1.04	1.09	1.13	1.32	1.29	0.91	1.06
September	0.16	0.15	0.12	0.22	0.20[2/]	0.24	0.07	0.10
October	1.76	1.83	1.29	1.12	1.70	1.10	1.27	1.45
November	1.01	1.30	1.02	0.68	1.18	0.81	0.81	0.90
Seasonal								
Winter (Dec, Jan, Feb)	0.98	3.52	2.43	1.16	3.53	2.80	1.44	2.52
Spring (Mar, Apr, May)	3.66	6.06	5.44	3.33	4.78	4.59	3.95	4.16
Summer (Jun, Jul, Aug)	2.38[1/]	2.17	2.28	2.23	2.58	2.58	1.71	1.95
Fall (Sep, Oct, Nov)	2.93	3.28	2.43	2.02	3.08[2/]	2.15	2.15	2.45
Annual	9.95[1/]	15.03	12.58	8.74	13.97[2/]	12.12	9.25	11.08

[1/] Precipitation total increased by 0.18 inches to compensate for data loss in July

[2/] Precipitation total increased by 0.10 inches to compensate for data loss in September

gauges. Precipitation measured at the three sites by a total of eight gauges during the current year ranged from 8.74 to 15.03 inches. Based on historical comparisons of individual gauges, the current year was the wettest of the four years of record. Although the natural variability of precipitation is high in semi-arid regions, a substantial part of the range in values is thought to be due to different exposures and capture efficiencies of the gauges. Inspection of Table 2-27 reveals that the variability of precipitation on an annual basis among the three sites (located several miles apart) for one type of precipitation gauge does not exceed 1.5 inches, whereas the variability of precipitation among the gauges at one site (located tens of feet apart) exceeds 5 inches.

The weighing bucket gauges are thought to produce the most representative precipitation data, due to a better exposure and the improvement in winter capture efficiency through the use of snow shields. The tipping bucket gauges have historically recorded low amounts of precipitation (RBOSC MDP Monitoring Report 4), which may be due to a less efficient capture and measurement technique.

Table 2-28 presents the results of the precipitation measurements collected onsite to date. The best estimate of total precipitation over the past two years, based on data from the weighing bucket gauges, indicates that between 11 and 12 inches of precipitation fell during the 1977-78 reporting period, and between 14 and 15 inches fell during the current year.

The wettest month was May, when close to one-fourth of the total annual precipitation fell. Spring was the wettest season, with 35 - 40 percent of the annual precipitation, while summer was the driest season with approximately 15 percent of the annual total. There was a period of 38 days without measurable precipitation at Sites 1 and 2 during June and July of the current year.

Spring was also the wettest season during the 1977-78 reporting period, accounting for 40 - 45 percent of the total annual precipitation. Similarly, that summer was also the driest season with only 10 - 15 percent of the total annual precipitation.

Table 2-28 Summary of Precipitation Measurements Over the Total Four-Year Record at Tract C-a

	February 1975-January 1976			February 1976-January 1977			December 1977-November 1978			December 1978-November 1979		
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Tipping Bucket Gauge												
Winter	0.03	0.05	0.52	0.63	0.48	0.91	--	--	--	0.98	1.16	1.44
Spring	0.39	0.20	1.11	1.87	1.92	2.33	--	--	3.33	3.66	3.33	3.95
Summer	0.11	0.06	0.33	2.79	3.54	2.52	--	1.29[1/]	1.58	2.38	2.23	1.71
Fall	0.12	0.43	0.93	0.51[1/]	0.03[1/]	0.99	1.63	1.88	--	2.93	2.02	2.15
Annual	0.65	0.74	2.89	5.80[1/]	5.97[1/]	6.75	--	--	--	9.95	8.74	9.25
Weighing Bucket Gauge												
Winter							3.3	2.83		3.52	3.53	
Spring							5.15	5.19		6.06	4.78	
Summer							--	1.14[1/]		2.17	2.58	
Fall							3.21	2.21[1/]		3.28	3.08	
Annual							--	11.37[1/]		15.03	13.97	
Wedge Gauge												
Winter							2.28	1.56	1.70	2.43	2.80	2.52
Spring							4.27	4.63	3.98	5.44	4.59	4.16
Summer							1.82	1.21	1.57	2.28	2.58	1.95
Fall							2.94	2.70	2.32	2.43	2.15	2.45
Annual							11.31	10.10	9.57	12.58	12.12	11.08

[1/] Partial data only

E. Solar Radiation

1. Objective

Solar radiation is monitored to acquire a data base useful in interpreting air quality data.

2. Methods

The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 4 and are not repeated herein.

3. Results and Discussion

Table 2-29 compares the onsite values of maximum and mean solar radiation data obtained from Site 1 for the four years of record. The annual mean solar radiation for each of the four data periods was 0.3 langleys/min, equivalent to 430 langleys/day.

Table 2-29 Four-Year Maximum and Mean Solar Radiation Data (in Langleys/min) at Site 1 for Baseline and MDP Periods

Month	Baseline Period				MDP Period			
	February 1975 - January 1976		February 1976 - January 1977		December 1977 - November 1978		December 1978 - November 1979	
	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean
December	0.9	0.1	0.9	0.1	0.8	0.1	0.8	0.1
January	0.8	0.2	0.9	0.2	0.8	0.1	0.9	0.1
February	1.2	0.3	1.0	0.2	1.2	0.2	1.0	0.2
March	1.5	0.4	1.4	0.3	1.2	0.2	1.3	0.2
April	1.6	0.5	1.5	0.4	1.4	0.3	1.4	0.3
May	1.7	0.6	1.6	0.4	1.5	0.4	1.4	0.3
June	1.9	0.5	1.6	0.5	1.5	0.5	1.5	0.5
July	1.7	0.4	1.6	0.4	1.5	0.5	1.5	0.4
August	1.6	0.4	1.5	0.4	1.4	0.4	1.4	0.3
September	1.3	0.4	1.4	0.3	1.3	0.3	1.3	0.3
October	1.2	0.3	1.2	0.3	1.1	0.3	1.1	0.2
November	0.9	0.2	0.9	0.2	0.9	0.1	0.8	0.2
Seasons								
Winter	1.2	0.2	1.0	0.2	1.2	0.1	1.0	0.1
Spring	1.7	0.5	1.6	0.4	1.5	0.3	1.4	0.3
Summer	1.9	0.4	1.6	0.4	1.5	0.5	1.5	0.4
Fall	1.3	0.3	1.4	0.3	1.3	0.2	1.3	0.2
Annual	1.9	0.3	1.6	0.3	1.5	0.3	1.5	0.3

2.3 CLIMATOLOGY

This section presents a description of the general climatology of the region in which Tract C-a is located.

1. Objectives

It is the intent to establish a climatology by utilizing meteorological data collected from three sites surrounding the study area (defined as "onsite") and by comparison with both short-term and long-term climatic data available from stations in the region. The rugged topography of western Colorado causes variations in climate within short distances, and caution must be used when applying climatic generalizations to the whole area. Ideally, the most accurate way of characterizing the climatology of Tract C-a is to develop a long-term meteorological data base from meteorological data gathered onsite. The presently available onsite meteorological data base of four years cannot be construed as representative of the long-term climatic conditions in the tract area. However, the onsite data can be compared with similar short-term and long-term data in the region to identify site specific climatic idiosyncracies due to the orientation of mountain ranges and valleys, elevation and exposure.

2. Methods

The methods followed for collection of climatological data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

Figure 2-26 presents the sources of data in the northwest section of the State of Colorado, where Tract C-a is located at an average elevation of approximately 7000 feet above MSL. The weather station closest to the tract is Little Hills, located 15 miles to the northeast of the study area at an elevation of 6140 feet. The Meeker No. 2 station is located about 30 miles to the east-northeast at an elevation of 6350 feet. The Rangely station is located about 20 miles to the west-northwest at an elevation of 5220 feet. Grand Junction,

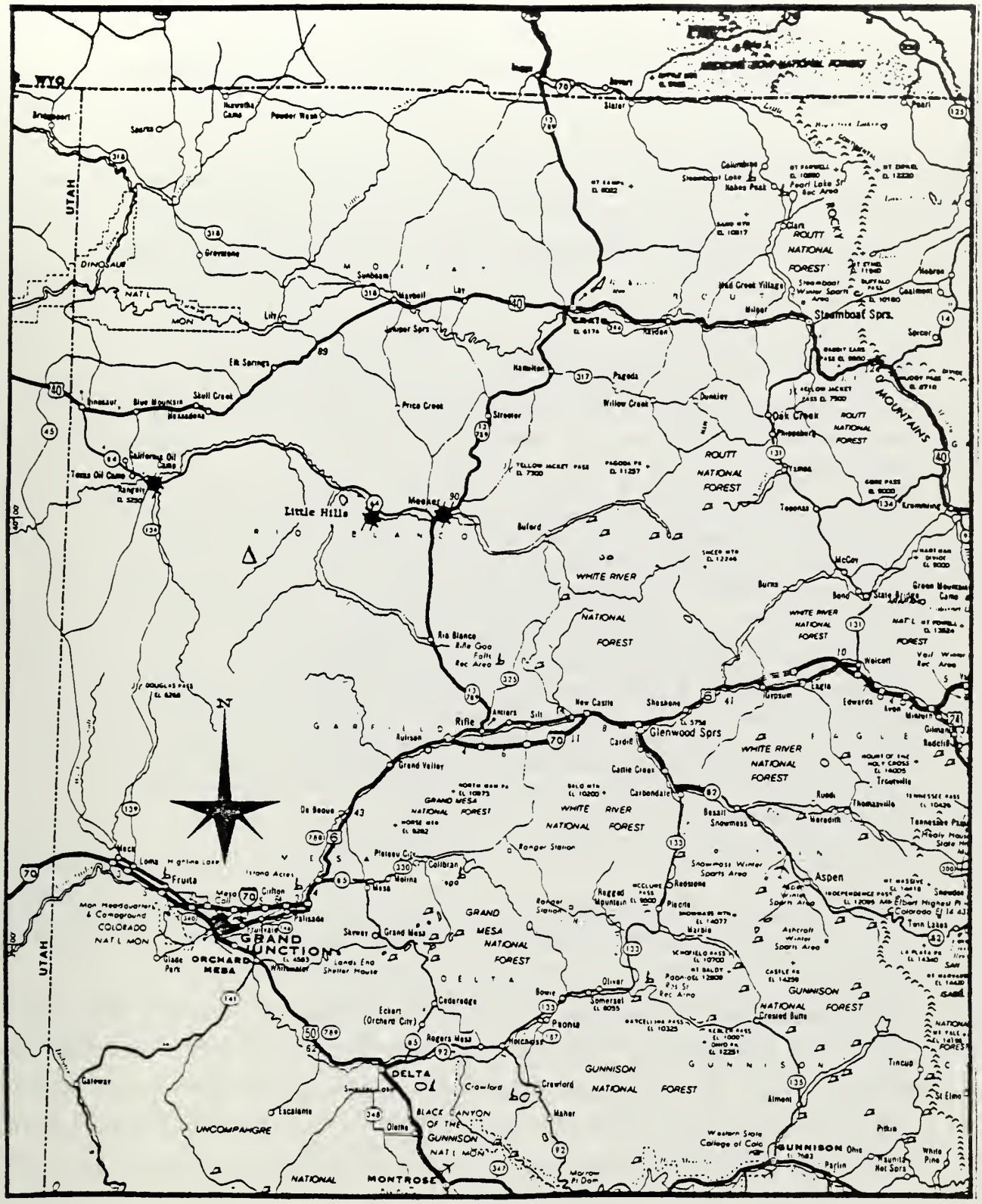


Figure 2-26. Map of Northwest Colorado Showing the Rio Blanco Region

at an elevation of 4843 feet, is about 60 miles south of the site. All of these stations monitor temperature and precipitation. At Grand Junction other parameters are measured as well.

The following is a discussion of the climatology of the area and the influences of the topography on the general meteorological and climatic conditions in the area. It has been extracted for references from the Baseline Report (RBOSP 1977):

> The Tract C-a area is surrounded by high mountains. As a result, many migratory low pressure systems are deflected around the region. Stationary high-pressure cells often persist for several days, their passage blocked by the Continental Divide east of Tract C-a. As a result, there is a high frequency of clear sunny days with light winds and large diurnal temperature changes. Gradient winds are generally westerly, existing throughout the year, except when interrupted by the passage of frontal systems. Precipitation measurements indicate relatively low annual accumulations such as those of semi-arid steppe regions. In addition, the data indicate a high degree of temporal and spatial variability in this area, which is to be expected given the rough terrain with its variations in elevation and exposure. The infrequent occurrences of precipitation, fog, and small light-scattering airborne dust have produced excellent visibility, in general, for the Tract C-a area.
>
> Local topography within the Tract C-a area has a much more pronounced effect on surface flows than the macroscale processes. Specific air movements produced by local conditions are often different from those expected from the major gradient flow. There is a tendency for wind velocities to be lowest at sunrise, when there is little vertical thermal mixing and the lower surface air does not couple with the more freely moving upper air. Conversely, velocities of local winds are greatest in the early afternoon hours when the air exhibits its greatest tendency to move vertically due to terrestrial heating, and couples with the faster air moving above it.

In the absence of strong gradient winds, the local terrain produces special meteorological conditions. During warm afternoon hours, the laterally constricted, but vertically expanding, air tends to flow up the valley. This air motion probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the valley side than the valley floor. At night, the reverse process occurs with the cold, dense air at higher elevations draining into the depressions. The greater radiative heat loss affecting the higher elevations (especially if they are snow covered) cools the air immediately adjacent to the surface, and this air sinks into the valley. Downward flowing cold air set in motion by this effect forms downslope winds leading to an accumulation of cold, dense, stable air in the valley bottom.

The high Cathedral Bluffs to the west of Tract C-a and the deep gulches to the east effectively channel surface winds, and thereby decouple the upper level flows from the surface flows much of the time. Several studies have shown that airflow within the canyons of the Piceance Creek and Yellow Creek Basins is influenced by drainage winds in their respective channels, whereas winds measured atop the ridge-like portions of the basin closely follow the gradient wind regime. It can be inferred that these drainage winds occur in conjunction with stronger temperature inversions within the valley than at the ridge regions.

Meteorological data collected at the site during the current year can be compared to data for the same period from Grand Junction and to the Grand Junction long-term averages for the period 1941-1970.

Table 2-30 presents the monthly departures from normal for Grand Junction mean temperature, total precipitation, mean relative humidity, and mean wind speed during the current year. The departure during the current year of the mean annual temperature at Grand Junction from the long term average was -2.8 F. The Grand Junction mean annual temperature exceeded the RBOSC Site 1 mean during the current year by 7.1 F. The annual precipitation at Grand Junction for the period was 1.52 inches above the long-term average, while the Site 1 annual precipitation was 6.62 inches above the Grand Junction long-term average. Site 1 mean wind speed was within 0.1 mph of the Grand Junction mean wind speed for the current year.

Table 2-30. Monthly Departures from the Long-term Normals for the Data Period December 1978 - November 1979 for Grand Junction and Comparison with Tract C-a Annual Values

		Temperature (F)			Precipitation (inches)			Relative Humidity[1] (%)			Mean Wind Speed (mph)		
	Month	Long Term Mean	1978-1979 Mean	Departure From Mean	Long Term Mean	Monthly 1978-1979 Mean	Departure From Mean	Long Term Mean	Monthly 1978-1979 Mean	Departure From Mean	Long Term Mean	Monthly 1978-1979 Mean	Departure From Mean
Grand Junction	December	29.5	16.0	- 13.5	0.55	1.30	+ 0.75	67	80	+ 13	5.9	4.3	- 1.6
	January	26.6	16.6	- 10.0	0.64	1.36	+ 0.72	70	78	+ 8	5.6	2.6	- 3.0
	February	33.6	23.4	- 10.2	0.01	0.63	+ 0.62	56	79	+ 23	6.7	2.5	- 4.2
	March	41.2	41.1	- 0.1	0.75	2.02	+ 1.27	44	67	+ 23	8.4	7.8	- 0.6
	April	51.7	52.4	+ 0.7	0.79	0.42	- 0.37	40	44	+ 4	9.7	8.7	- 1.0
	May	62.2	60.2	- 2.0	0.63	1.45	+ 0.82	34	51	+ 17	9.6	9.8	+ 0.2
	June	71.3	71.0	- 0.3	0.55	0.78	+ 0.23	31	30	- 1	9.8	9.8	0.0
	July	78.7	78.6	- 0.1	0.46	0.08	- 0.38	33	30	- 3	9.3	9.7	+ 0.4
	August	75.4	74.6	- 0.8	1.05	0.61	- 0.44	35	38	+ 3	9.0	9.3	+ 0.3
	September	67.2	72.0	+ 4.8	0.84	0.01	- 0.83	38	24	- 14	9.0	9.2	+ 0.2
	October	54.9	58.9	+ 4.0	0.93	0.25	- 0.68	44	34	- 10	7.9	8.6	+ 0.7
	November	39.8	33.2	- 6.6	0.61	1.02	+ 0.41	57	61	+ 4	6.6	6.9	+ 0.3
	Annual	52.7	49.8	- 2.9	8.41	9.93	+ 1.52	46	51	+ 5	8.1	7.4	- 0.7
RBOSC Site 1		NA	42.5	NA	NA	15.03	NA	NA	50	NA	NA	7.3	NA
RBOSC departure from Grand Junction		NA	- 7.3	NA	NA	5.10	NA	NA	- 1	NA	NA	- 0.1	NA
RBOSC Site 1 4-yr Mean[2]		44.1			8.20				38		7.5		

[1] Based on daily averages of four readings

[2] The RBOSC 4-year mean data does not constitute a long term mean

NA - Not available

Table 2-30 indicates that Grand Junction data compares rather poorly with onsite data. The mean annual temperature decrease of 7 F and the total annual precipitation increase of 4 inches from Grand Junction to Tract C-a has been relatively constant for the last two years (RBOSC MDP Monitoring Report 3). Consequently, Grand Junction data should be used very cautiously in describing the climatology of the tract. This result is not unexpected, since Grand Junction is located in a valley approximately 2500 feet lower than Site 1. In fact, an estimate can be made of the temperature that would be expected if the Grand Junction station was at the same altitude as Site 1, by using the NACA Standard Atmosphere lapse rate for 40°N latitude of 3.57 F/1000 ft (Hess 1959). Using this approximation, the Grand Junction mean annual temperature would be reduced by 8.9 F. Thus, most of the large discrepancy in mean annual temperatures between the site and Grand Junction can be accounted for by the altitude differential. However, it should be emphasized that topographic influences can also be large; whereas the standard lapse rate indicates that Site 3 should have a mean annual temperature 2.8 F higher than Site 1, the actual mean annual Site 3 temperature for the current year is 1 F lower than Site 1.

Table 2-31 presents monthly temperature data collected during the current year from Site 1, three surrounding climatological stations (Rangely, Meeker No. 2, and Little Hills), and Grand Junction. The table shows that Grand Junction temperature data are not very representative of at least part of Rio Blanco County. The mean monthly and annual temperatures at the three climatological stations in the county agree well with the onsite data, especially considering the elevation and topographic differences among the sites. A major difference between Site 1 and the other stations is evident, however, in the average temperature range compared to the other local stations. This is due primarily to the relative location of the instruments. All climatological stations measure temperature 6 feet above the ground in a standard weather shelter, whereas the Site 1 temperature sensor is located at 10 m (33 ft). Since temperature changes in the lower layers of the atmosphere result from heat transfer from the ground surface, the diurnal temperature range will decrease with height above the ground. Thus, the reduced temperature range at Site 1 relative to the surrounding station is largely due to the increased height of the temperature sensors at Site 1.

Table 2-31. Comparison of Monthly Temperature (F) in the Vicinity of Tract C-a for the Data Period December 1978-November 1979

Month	Tract C-a Site 1			Little Hills			Meeker No. 2			Rangely			Grand Junction		
	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean	Avg Max	Avg Min	Mean
December	24.3	11.7	18.0	29.6	-0.4	14.6	30.1	6.4	18.2	22.6	-4.2	9.2	25.3	6.7	16.0
January	21.4	10.0	15.7	27.3	-0.3	13.5	28.0	3.6	15.8	19.7	-7.8	6.0	25.2	7.9	16.6
February	31.1	21.0	26.0	41.5	7.6	24.6	40.7	13.7	27.2	32.5	3.4	18.-	33.1	13.8	23.4
March	36.3	25.7	31.0	45.6	19.7	32.6	45.8	22.3	34.0	46.2	23.2	34.7	50.5	31.7	41.1
April	46.6	33.1	39.8	58.2	22.0	40.1	58.1	26.6	42.4	63.1	32.9	48.0	64.7	40.2	52.4
May	55.6	42.3	49.0	66.0	32.7	49.4	65.9	37.0	51.4	70.6	41.0	55.8	72.3	48.2	60.2
June	69.3	54.5	61.9	79.8	36.3	58.0	79.8	41.2	60.5	85.7	48.7	67.2	86.1	55.9	71.0
July	77.2	60.4	68.8	86.0	41.2	63.6	85.7	47.6	66.6	92.5	55.1	73.8	94.2	63.1	78.6
August	70.5	56.7	63.6	81.1	41.7	61.4	81.4	48.0	64.7	87.8	54.0	70.9	88.3	60.8	74.6
September	71.6	55.9	63.8	81.4	32.5	57.0	80.5	40.5	60.5	86.6	46.6	66.6	86.7	57.3	72.0
October	52.7	39.2	46.0	67.0	23.5	45.2	66.8	30.8	48.8	70.5	34.3	52.4	72.3	45.5	58.9
November	31.8	21.7	26.8	40.9	8.5	24.7	40.6	13.3	27.0	41.7	13.7	27.7	43.4	23.0	33.2
Annual			42.5			40.4			43.1			44.2			49.8

Table 2-32 presents a comparison of Site 1 precipitation with data from surrounding stations for the current year. Monthly precipitation amounts at all of the stations vary widely due to the complex orographic influences of the region and the intermittent nature of precipitation in the region, but annual totals are reasonably close. Grand Junction had the lowest monthly precipitation totals of all stations because of its protection by surrounding higher terrain.

The mean daily solar radiation received at Grand Junction (based on a 10-year period) is 456 langleys/day (Baldwin 1974). This compares to an average of 432 langleys/day recorded at Site 1 during the four years of data collection.

Table 2-32. Comparison of Monthly Precipitation (inches) in the Vicinity of Tract C-a for the Data Period December 1978-November 1979

Month	Tract C-a Site 1	Little Hills	Meeker No. 2	Rangely	Grand Junction
December	1.73	1.48	1.14	M	1.30
January	1.14	0.93	0.71	M	1.36
February	0.65	0.61	0.80	0.52	0.63
March	1.82	2.45	1.84	2.18	2.02
April	0.85	1.02	1.03	0.85	0.42
May	3.39	2.68	2.53	1.12	1.45
June	0.36	0.32	0.37	0.57	0.78
July	0.77	0.28	0.78	1.07	0.08
August	1.04	1.30	1.09	0.63	0.61
September	0.15	0.25	0.50	0.13	0.01
October	1.83	1.56	1.21	1.17	0.25
November	1.30	1.66	1.21	0.60	1.02
Annual	15.03	14.54	13.21	M	9.93

M = Missing Data

2.4 QUALITY ASSURANCE AND DATA RECOVERY

The data summaries incorporated in the Appendices, with the exception of precipitation and particulate data, were prepared from data acquired by an automatic data acquisition system located on Tract C-a. The data are recorded both on magnetic tape and analog strip chart recorders. A comprehensive quality assurance program has been maintained to ensure the reliability and accuracy of the data. This program includes documentation by the site technician of all calibrations and system malfunctions, weekly zero and span calibrations of the air quality instrumentation, utilization of control charts onsite to detect drifting in the weekly data, quarterly calibrations of the air quality instrumentation by both the internal technical staff and an independent auditing team, semi-annual calibrations of the meteorological instrumentation, and review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated using pollutant sources traceable to National Bureau of Standards (NBS) standards. The carbon monoxide and the nitrogen oxide analyzers were calibrated using a known concentration of test gases which had been certified by the vendor. Calibration of the sulfur dioxide instrument was conducted with a permeation tube source using a Monitor Labs calibrator. The ozone analyzer is calibrated using the gas phase titration method.

Each instrument was tested at least once a week by inserting a zero pollutant concentration and at least one upscale concentration. These tests provided data on instrument drift and insured that the instrument would respond to a sensible level of pollutant concentration in the ambient air.

The quarterly field calibrations were used to determine the accuracy of the instruments. No correction factors were required to adjust the data. Independent quarterly audits by an EPA contractor (Rockwell International) were used to check the internal calibration methods and were not used to adjust the data during this period. Almost all of the audited instruments were within ±10 percent of the auditor's equipment, which conforms with EPA guidelines. The maximum deviation found during the year was 11 percent.

The air quality data summaries include many hours where the concentration of some pollutants fell below the reliable threshold of detection of the instrument (based on the manufacturer's specifications). When this occurred, a number equal to one-half the threshold value was substituted for the data point. This procedure is adopted from the EPA Quality Assurance Handbook, Air Pollution Measurement, Vol. 1. This applied to sulfur dioxide, hydrogen sulfide, nitrogen oxides and carbon monoxide data acquired through much of the data period.

The meteorological system is calibrated on a semi-annual basis. This includes routine replacement of all wind speed and wind direction sensors. No correction factors were required to adjust the data.

Data recoveries for all meteorological and air quality parameters collected by the onsite data acquisition system are presented in Tables 2-33 and 2-34. With the exception of SO_2 and H_2S, the data recovery for all parameters have been above the 75 percent level recommended by the EPA. As discussed earlier, the poor data recovery for H_2S and SO_2 was due to two older analyzers which had chronic maintenance problems. New state-of-the-art pulsed fluorescent analyzers have recently been installed as replacements, so future data recovery for these parameters should now easily meet EPA's criterion.

Table 2-33. Annual Data Recovery (%) of Meteorology Parameters Monitored at Tract C-a for the Period December 1978-November 1979

Parameter	Data Recovery (%)
Site 1	
10 m wind speed	87
10 m wind direction	88
60 m wind speed	88
60 m wind direction	88
10 m temperature	87
60 m temperature	87
ΔT 60-10 m	87
dew point/relative humidity	86
solar radiation	85
Site 2	
10 m wind speed	86
10 m wind direction	86
10 m temperature	86
Site 3	
10 m wind speed	87
10 m wind direction	87
10 m temperature	87

Table 2-34. Annual Data Recovery (%) of Air Quality Parameters Monitored at Tract C-a for the Period December 1978-November 1979

Parameter	Data Recovery (%)
Site 1	
O_3	86
CO	87
NO	85
NO_x	85
H_2S	3
SO_2	40
Site 3	
O_3	85
H_2S	32
SO_2	40

2.5 VISIBILITY

Documentation of visibility in the Piceance Creek Basin is a cooperative study conducted by the Rio Blanco Oil Shale Company and the Cathedral Bluffs Oil Shale Company (formerly C-b Shale Oil Venture).

1. Objectives

The objectives of this program are to document the visibility in the area of the Piceance Creek Basin and identify trends or variations in visibility which may be evident during the monitoring program. The results of this program will provide visibility data against which past and future data may be compared and with which concurrent meteorological and air quality data may be incorporated for further evaluation and consideration.

2. Methods

Two methods are being employed in the documentation of basin-wide visibility during the Spring and Fall studies. A photometric method incorporates techniques identical to those utilized during the baseline study and described in RBOSC MDP Monitoring Report 1. A second method, which has been newly instituted during the current year, involves use of a telephotometer to derive visual ranges. The results of the two methods will be compared when the telephotometer data are reduced in the near future. Data are collected every third day from a centrally located shelter (Figure 2-27) during two seasons: the Spring, represented by April, May, and June, and the Fall, represented by October and November. Visibility measurements presented in this report were obtained during the Spring and Fall seasons, 1979.

3. Results and Discussion

This analysis, similar to the earlier studies in 1975-76 and 1978, is based only on the photometric data. Comparisons between the two methods will be made after reduction of the telephotometer data has been completed.

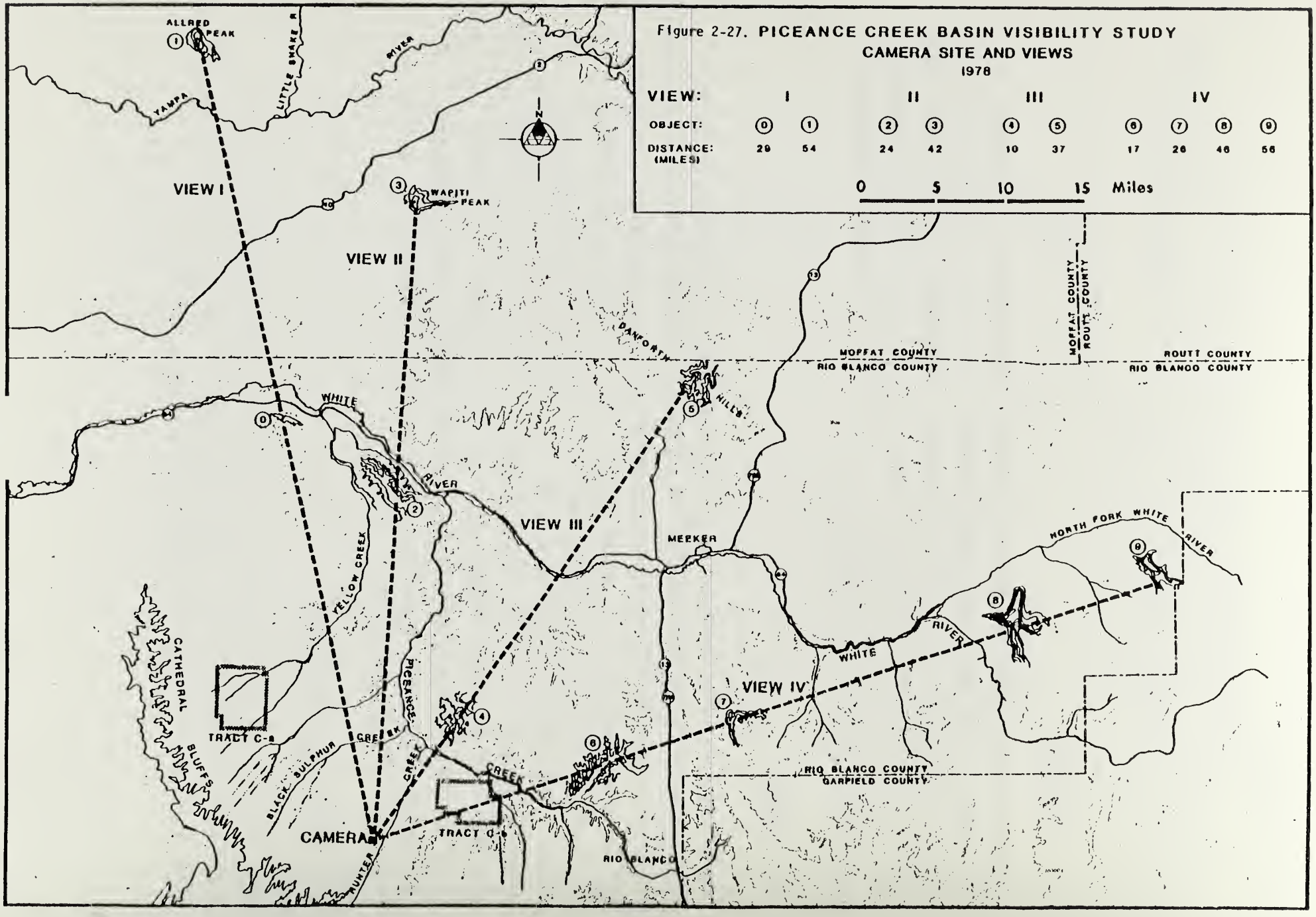


Figure 2-27. PICEANCE CREEK BASIN VISIBILITY STUDY
CAMERA SITE AND VIEWS
1978
VIEW: I II III IV
OBJECT: 0 1 2 3 4 5 6 7 8 9
DISTANCE (MILES): 29 54 24 42 10 37 17 26 46 56
0 5 10 15 Miles
ALLRED PEAK
YAMPA RIVER
LITTLE SNAKE R
WAPITI PEAK
VIEW I
VIEW II
VIEW III
VIEW IV
CAMERA
DANFORTH HILLS
MOFFAT COUNTY
RIO BLANCO COUNTY
ROUTT COUNTY
RIO BLANCO COUNTY
WHITE RIVER
YELLOW CREEK
MEEKER
NORTH FORK WHITE RIVER
CATHEDRAL BLUFFS
TRACT C-a
BLACK SULPHUR CREEK
PICEANCE CREEK
TRACT C
HUNTER CREEK
RIO BLANCO
RIO BLANCO COUNTY
GARFIELD COUNTY

During the 1979 monitoring period, visual range measurements were made on 16 of the 20 scheduled days of photography over a five month period. Late snows prevented the program from beginning before mid-April, and heavy snows terminated the program in mid-November. Of a possible 560 scheduled visual range measurements, 414 valid measurements were obtained, for a 74 percent data recovery.

Measurements of visual range during the year were occasionally hampered by passing rain or snowshowers which restricted visibility and made photography of the views difficult. Accumulations of snow on some objects being photographed required adjustments to be made in their albedo. The resulting albedo for these objects was estimated using the original albedo of the object modified by the relative contribution of the snow. The albedo values used for the original objects' surfaces and for the additional snow cover were based on the spectral reflectance of snow and various soil types listed in the Handbook of Geophysics and Space Environments (Valley 1975).

Visual range measurements have now been taken over three periods which can be compared: Fall 1975 and Spring 1976, which represent the baseline period; Spring and Fall of 1978, and Spring and Fall of 1979, which represent the MDP period.

a. Evaluation of visual range on a daily basis - The computation of a daily mean visual range provides an indication of the prevailing visibility and conditions found in an area during the course of a day, unbiased by short-term or directional anomalies. Daily mean, maximum, and minimum visual ranges in the Piceance Creek Basin were calculated for each day of monitoring and the results are presented in Table 2-35.

The daily mean visual ranges obtained during 1979 were generally high and occurred most frequently between 90 and 100 miles, although mean visual range varied from 50 to 101 miles. The hourly visual ranges used to compute the daily mean visual ranges for the Spring and Fall monitoring periods are included in Appendices 2-5.1 and 2-5.3, respectively. A description of visual and meteorological conditions existing on the sampling days are presented as Site Log Sheets in Appendices 2-5.2 and 2-5.4.

Table 2-35. Daily Mean Visual Range (Miles) Piceance Creek Basin, Colorado Spring and Fall, 1979

	Date	Mean Visual Range	Hourly Min./Max.
Spring			
	April 18, 1979	62	52/73
	24	64	43/86
	30	74	65/84
	May 6, 1979	50	36/69
	18	66	51/83
	24	95	58/154
	30	101	57/139
	June 5, 1979	71	54/89
	11	99	78/117
Fall			
	October 10, 1979	82	64/104
	16	77	50/112
	25	98	77/116
	28	100	61/137
	November 3, 1979	80	42/132
	9	51	25/74
	15	99	78/119

Large fluctuations in the mean visual range of consecutive days of photography were common during 1979 with variations ranging from 2 to 8 miles. Between November 9 and 15, 1979, for example, the mean visual range increased from 51 to 99 miles. However, between October 25 and 28, 1979, the mean visual range changed by only 2 miles, from 98 miles to 100 miles. The fluctuations exhibited in 1979 were about the same as comparable periods in the earlier studies. The average change in consecutive days of photography during the Spring and Fall of 1979 was 18 miles, compared with 16 miles during 1978 and 28 miles during the baseline period (1975-76).

The daily mean visual range is computed as an average of the visual ranges in each of four views (Figure 2-28). The increases or decreases in daily mean visual range, evident in Table 2-35, were generally matched by similar increases or decreases in the visual range at each view. These fluctuations, shown in Figure 2-28, illustrate the similar response to changes in visibility which each view exhibited. The correlation between fluctuations in daily mean visual ranges among the views implies that the influences on visibility were widespread and generally uniform in the way they affected visibility.

b. Evaluation of visual range on a monthly basis - Monthly mean visual ranges were calculated from measurements obtained from all the views and hours during each month of monitoring. The monthly mean visual ranges obtained in the Piceance Creek Basin Area during the Spring and Fall monitoring periods are listed in Table 2-36. Values obtained during comparable periods in 1975-76 and 1978 have been included for review and comparison with the 1979 data.

Monthly mean visual ranges obtained during the five months of monitoring in 1979 range from 67 miles in April to 89 miles in October. The values obtained in May and October were more similar during the three years than were the April and November values. The monthly mean visual ranges for May and October had a maximum difference among the three years of record of 8 miles, while the monthly means for April and November varied between years by as much as 29 miles. It is unlikely that this is a significant relationship because these mean values are based on a very few sample days (a maximum of five days under ideal conditions, but as an extreme example, November 1978 had only one full and three partial days of visibility data).

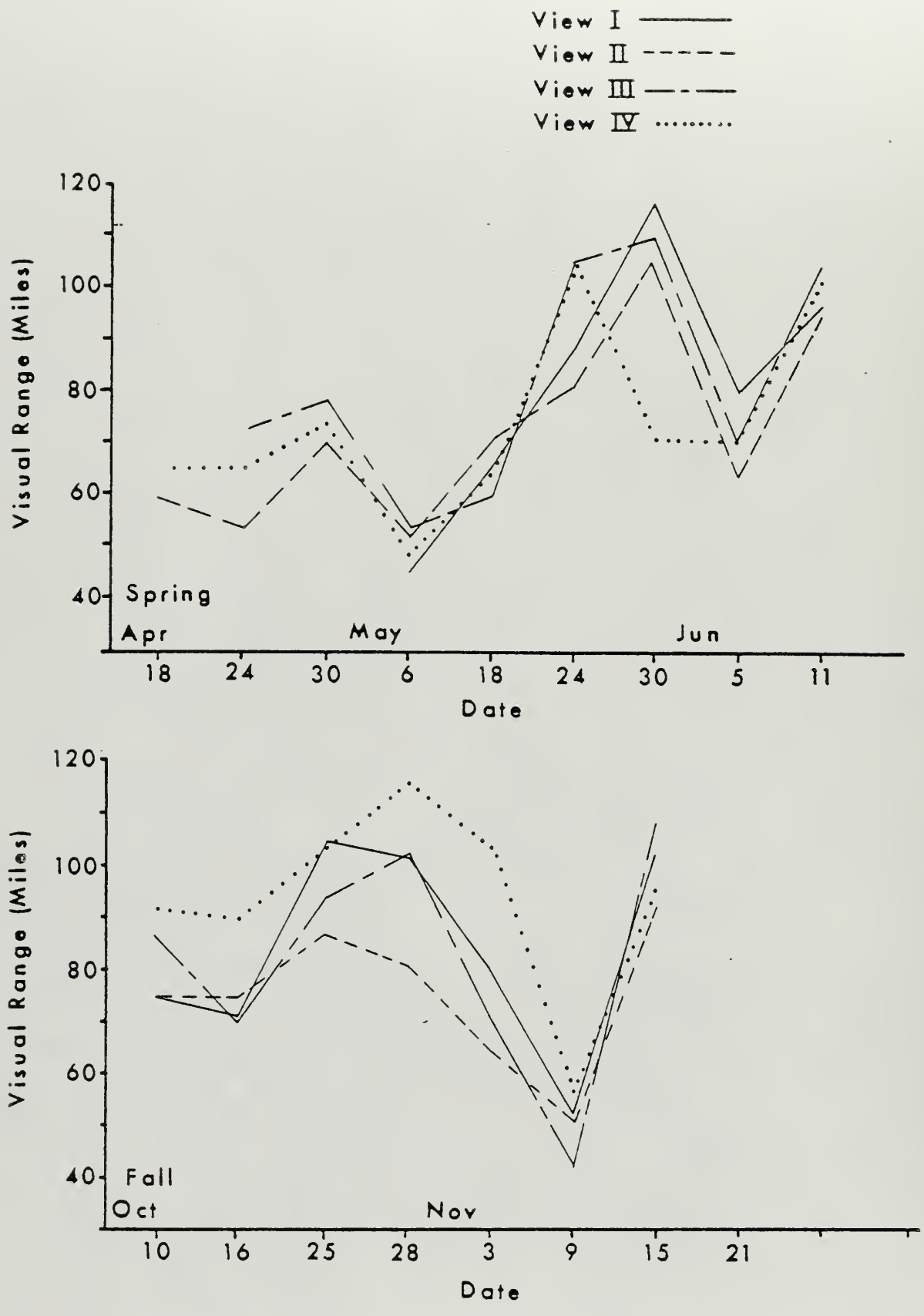


Figure 2-28. Daily Mean Visual Range for each View, Spring and Fall 1979, Piceance Creek Basin, Colorado

Table 2-36. Monthly Composite Visual Range Comparison (Miles) During Spring and Fall for 1975-1976, 1978 and 1979, Piceance Creek Basin, Colorado

Month	Mean[1]	Maximum	Minimum	Standard Deviation
April 1979[2]	67	86	43	9.9
April 1978	83	142	21	21.1
April 1976	67	138	14	27.7
May 1979	78	154	36	26.9
May 1978	74	132	17	20.5
May 1976	70	124	27	16.7
June 1979[3]	85	117	54	16.7
June 1976	71	117	45	14.8
October 1979	89	137	50	17.2
October 1978	84	130	50	16.2
October 1975	89	144	44	24.6
November 1979	77	132	25	25.1
November 1978[4]	70	121	22	26.4
November 1975	99	149	24	29.0

[1] Monthly means are based on approximately five days of photography per month

[2] Values based on two full days and one partial day of photography

[3] Values based on two full days of photography

[4] Values based on one full day and three partial days of photography

The highly variable meteorological conditions encountered on such a small sample could easily cause a considerable change in the monthly average with just one day of very good or very poor weather.

Hourly maximum and minimum visual range measurements for each month are also listed in Table 2-36. Except for April, which only had two full sampling days in 1979, the monthly maximum and minimum visual ranges are quite similar. The absolute minimum and maximum visual ranges encountered during the three years of sampling were 14 and 149 miles in 1975-76, 17 and 142 miles in 1978, and 25 and 154 miles in 1979.

c. Evaluation of visual range on a seasonal basis - Visual range measurements were made from mid-April to mid-June in the Spring of 1979 and in October and November in the Fall of 1979 to quantify and characterize the visibility of the area. The selection of these seasons for data collection was based on the results of the initial study (1975-76), which indicated that the seasonal mean visual range was at a minimum during the Spring and at a maximum during the Fall. Discussions in this section of the report deal with a comparison of visibilities measured during these two seasons in 1979, and with data obtained during the two earlier years of record.

The visual ranges obtained within the Piceance Creek Basin during the two seasons in 1979 were generally high; the mean visual ranges were 69 miles during the Spring and 91 miles during the Fall. These and additional statistical descriptors are listed in Table 2-37 for each season and for the comparable seasons in 1978 and 1975-76. The data for 1975-76, however, includes three months per season, although the sampling frequency (once per six days) was identical.

During the Spring of 1979, visual ranges were generally high; 95 percent of the visual range measurements were greater than 46 miles, 50 percent were greater than 72 miles. This compares with fifth and fiftieth percentile visual ranges of 43 and 81 miles in the Spring of 1978, and 39 and 67 miles in the Spring of 1976, respectively. The mean visual ranges during the Fall have been higher than the Spring in each of these sampling years. Ninety-five percent of the visual range measurements during the Fall of 1979 were greater than 42 miles;

Table 2-37. Seasonal Composite Visual Range Summary (Miles) for Spring and Fall 1975-76, 1978, and 1979, Piceance Creek Basin, Colorado

Season	Mean			Hourly Maximum			Hourly Minimum			Fifth Percentile			Standard Duration		
	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979
Spring	69	79	77	138	142	154	14	17	36	39	43	46	21.1	21.2	22.2
Fall	91	80	84	149	130	137	24	22	36	45	43	42	27.3	20.5	21.9

50 percent were greater than 87 miles. This compares with fifth and fiftieth percentile ranges of 43 and 82 miles in the Spring of 1978 and 45 and 92 miles during the Fall of 1975, respectively.

The seasonal composite visual range summary is shown for the Spring and Fall for each of the three years in Figures 2-29 through 2-31. The figures illustrate that there is a definite shift toward higher visual ranges from Spring to Fall in 1979 and 1975-76. A seasonal change is less apparent in 1978, although there is a lower frequency of low visual range data in the Fall compared to the Spring. These figures are reinforced by the data based on Table 2-37, which show that the change in the mean visual range from Spring to Fall was 7 miles in 1979, 22 miles in 1975-76, but only 1 mile in 1978.

Part of the reason that there was only a minimal seasonal shift in mean visual range for 1978 is apparent upon close inspection of Table 2-38. The hourly maximum visual ranges in the Fall of 1978 are much below the maximum for the other years in three of the four records. Consequently, the absence of the shift in 1978 may be due only to the lack of one or two clear days -- it should also be noted that the data recovery for November 1978 was low, so the data base is smaller.

Table 2-38 shows the seasonal visual range summary for each view during all three years of record. The table indicates that the mean visual range data from 1978 and 1979 are fairly similar for each of the four views during each of the two seasons. The baseline year (1975-76) in comparison with the two latest years appears to generally have lower mean visual ranges in the Spring, and higher mean visual ranges in the Fall.

d. Evaluation of visual range on an annual basis - Visual range measurements made during 1979 were generally high with an annual mean visual range of 80 miles. This compares with an annual mean of 79 miles during the two earlier years of study (Table 2-39). The range of values obtained was also quite high; visual ranges in 1979 varied from 25 miles to 154 miles. The distribution of these values is presented in Figure 2-32. Distributions for 1978 and 1975-76 are presented in Figures 2-33 and 2-34 for comparative purposes.

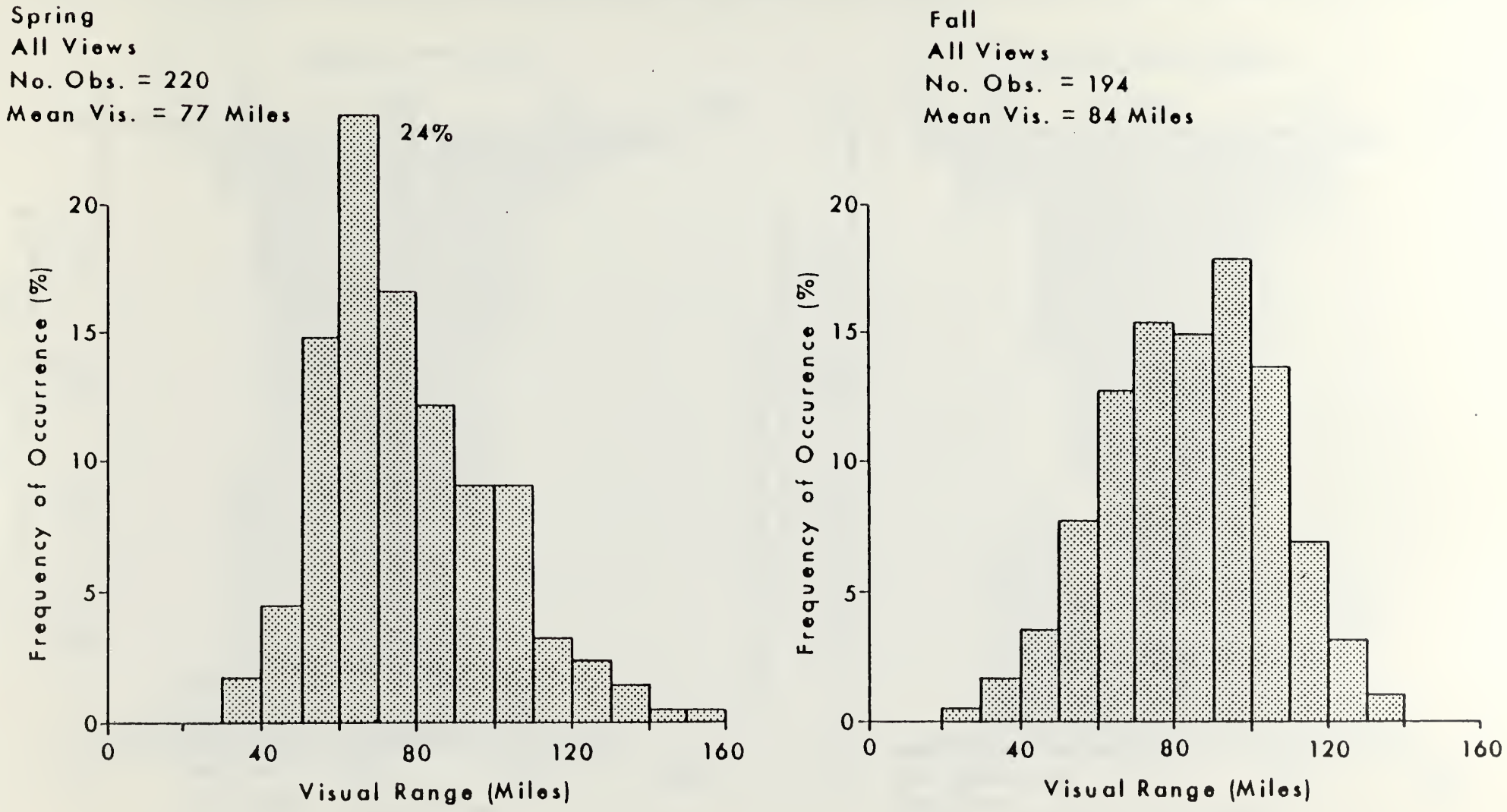


Figure 2-29. Seasonal Composite Distribution of Visual Range, Spring and Fall 1979, Piceance Creek Basin, Colorado

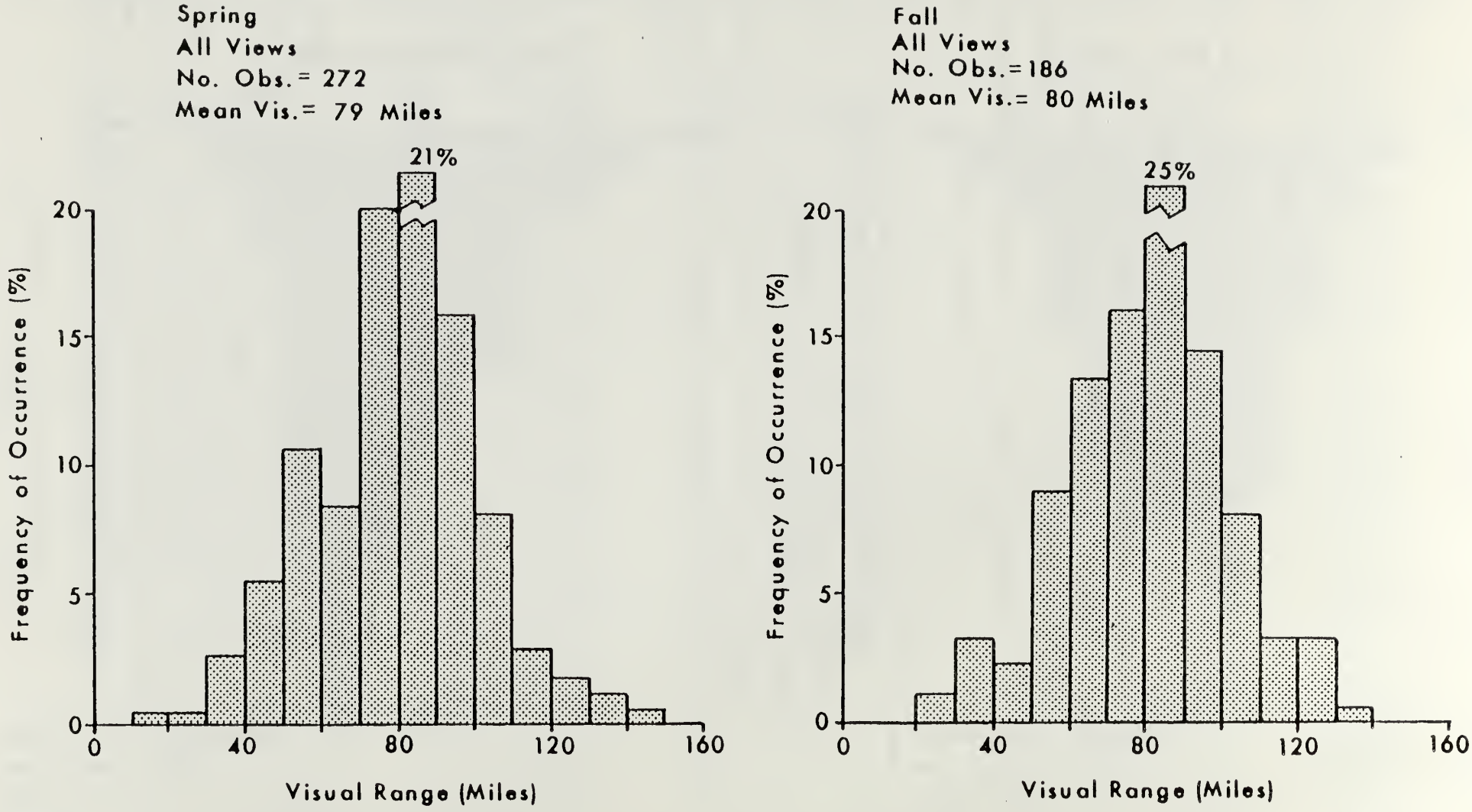


Figure 2-30. Seasonal Composite Distribution of Visual Range, Spring and Fall 1978, Piceance Creek Basin, Colorado

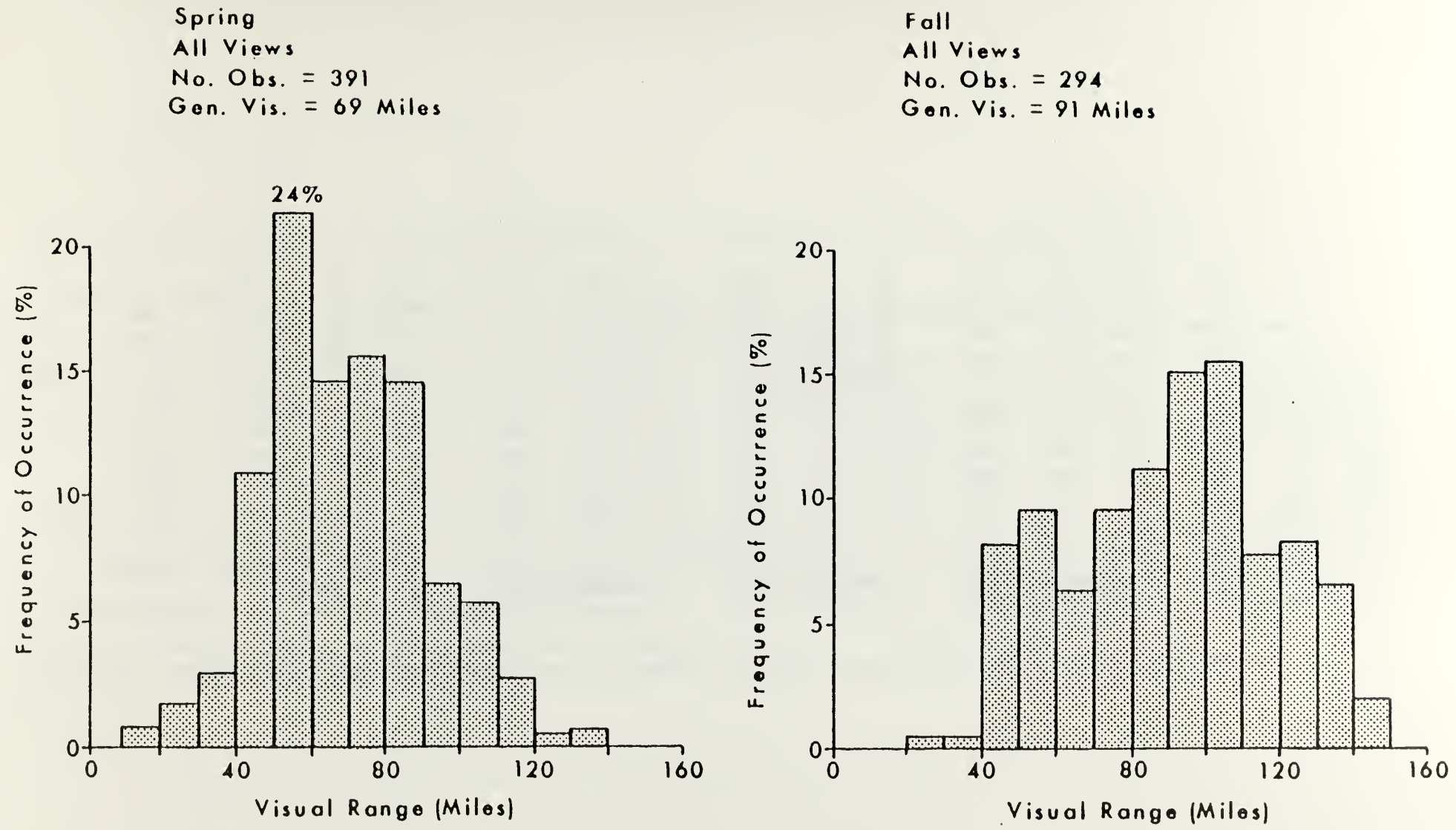


Figure 2-31. Seasonal Composite Distribution of Visual Range, Fall 1975 and Spring 1976, Piceance Creek Basin, Colorado

Table 2-38. Seasonal Visual Range Summary (Miles) for Three Periods: Fall 1975 and Spring 1976, Spring and Fall 1978, and Spring and Fall 1979, in the Piceance Creek Basin, Colorado

		Mean			Hourly Maximum			Hourly Minimum			Fifth Percentile			Standard Deviation		
	View	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979
Spring	I	74	81	81	118	126	139	39	51	36	50	53	36	18.9	16.5	23.7
	II	63	73	73	113	112	129	32	32	43	40	42	46	16.5	17.1	19.4
	III	67	77	82	118	132	154	14	17	44	27	35	45	22.3	23.7	24.9
	IV	73	84	74	138	142	141	27	35	39	38	45	46	24.5	24.8	20.3
Fall	I	93	87	84	149	130	126	37	58	41	49	54	50	27.8	16.5	20.8
	II	77	76	76	142	102	132	42	55	41	43	54	45	23.6	11.7	16.6
	III	92	71	82	146	103	128	24	22	25	46	31	30	27.4	21.9	24.5
	IV	101	86	94	148	125	137	48	31	36	52	44	41	25.8	24.5	21.7

Table 2-39. Annual Visual Range Summary (Miles) for Three Periods: 1975-76, 1978, and 1979, in the Piceance Creek Basin, Colorado.

View	Mean			Hourly Maximum			Hourly Minimum			Fifth Percentile			Standard Deviation		
	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979	1975-76	1978	1979
I	83	83	83	149	130	139	31	51	36	50	53	41	23.0	16.7	22.1
II	69	74	74	142	112	132	31	32	41	42	46	46	19.2	15.2	18.1
III	78	74	82	149	132	154	14	17	25	35	33	40	26.6	23.0	24.6
IV	85	85	83	148	142	141	22	31	39	41	45	46	28.8	24.6	23.1
Composite	79	79	80	149	142	154	14	17	25	41	43	46	25.3	20.9	22.3

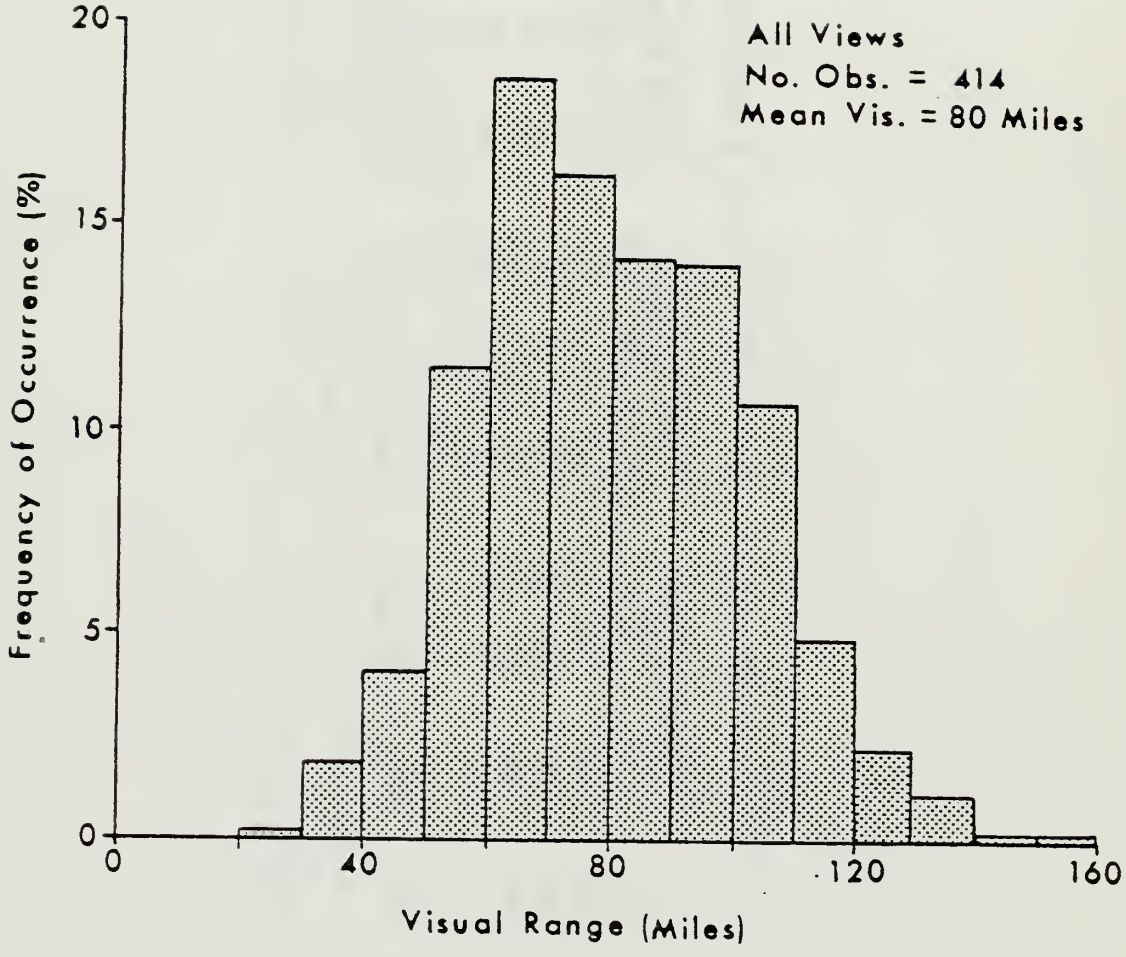


Figure 2-32. Annual Composite Distribution of Visual Range, 1979, Piceance Creek Basin, Colorado

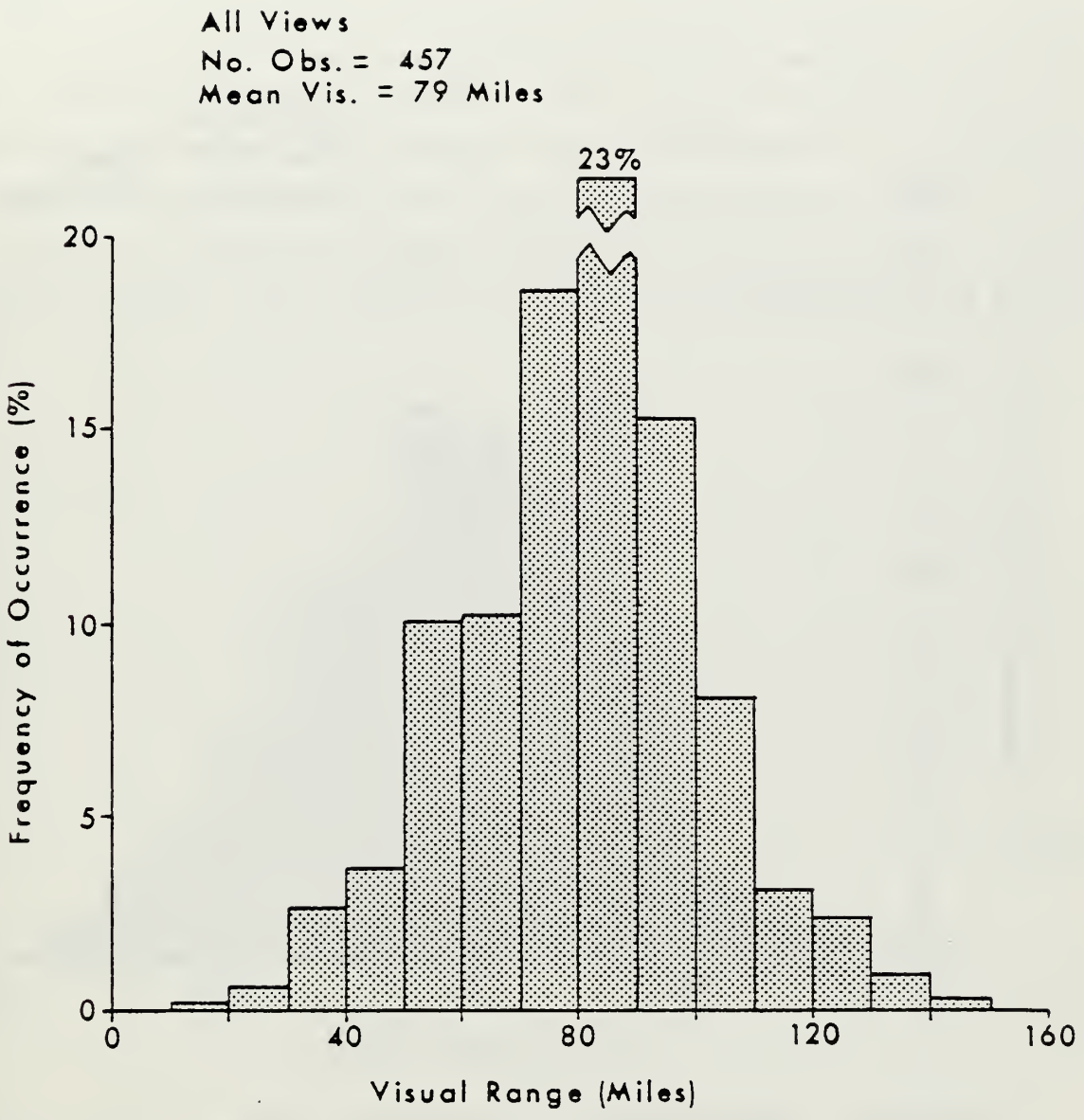


Figure 2-33. Annual Composite Distribution of Visual Range, 1978, Piceance Creek Basin, Colorado

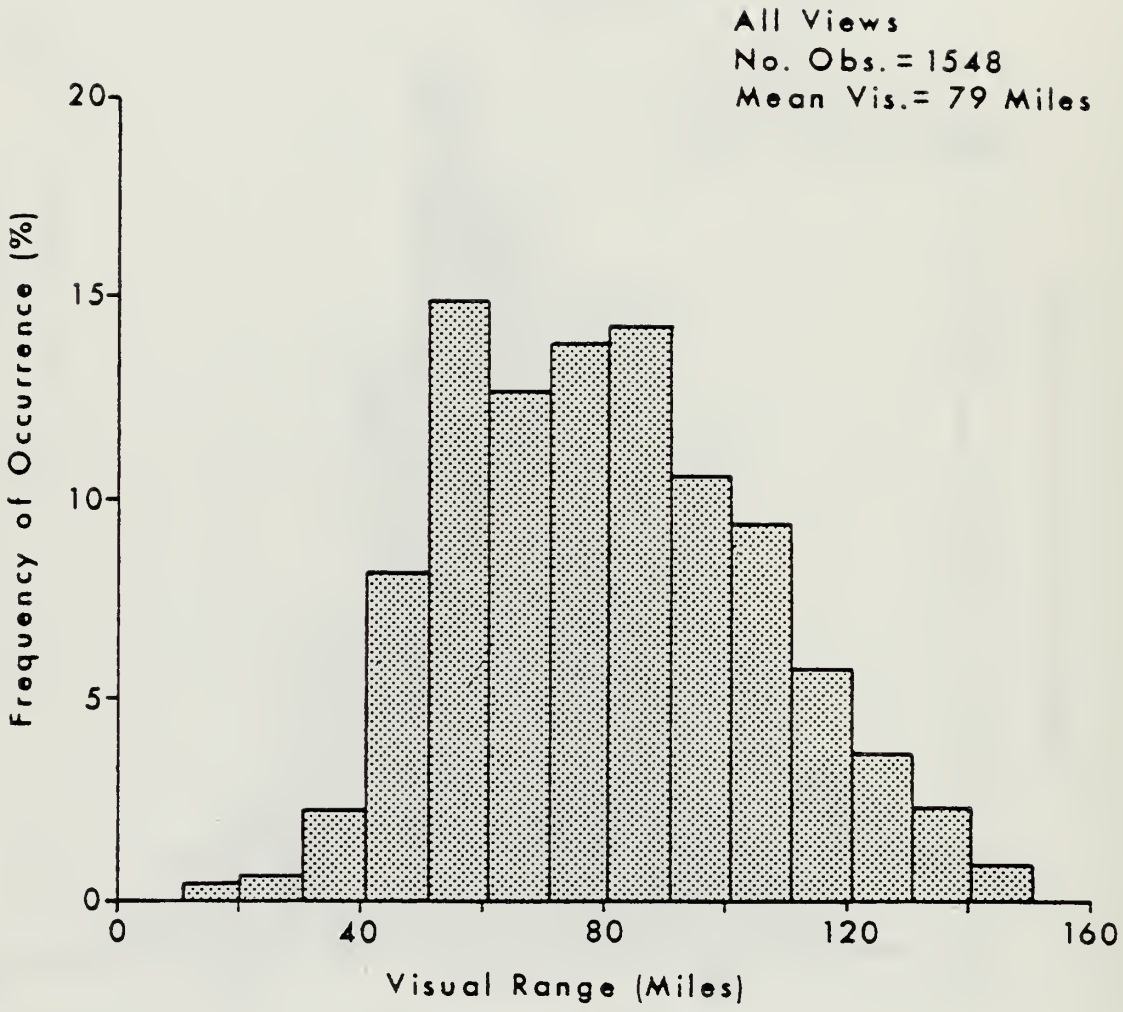


Figure 2-34. Annual Composite Distribution of Visual Range, 1975-76, Piceance Creek Basin, Colorado

Hourly maximum visual ranges obtained during the year varied among the views; maximum values from 132 miles in View II to 154 miles in View III were recorded. Hourly minimum visual ranges varied somewhat less than the maximum values, ranging from 25 miles in View III to 41 miles in View II.

This summary of the visibility data has shown that there has been no apparent change in the mean visual range measured at the Hunter Creek site since the original study was conducted in 1975-76. As a review of the data indicates (presented in the tables of this section and in Appendices 2-5.1 and 2-5.3), there is at least as much variation in visual range among the views and between days as there is in the year-to-year variation. That is, no trend in the data is currently evident, being completely masked by the background noise of the system.

2.6 NOISE

Development activities on Tract C-a will result in increased noise levels in the area. In order to assess the potential effects of these increased noise levels, it will be necessary to identify the sources of the noise and the intensity of noise levels at various distances from these sources. The RBOSC noise survey is designed to provide these data.

1. Objectives

Regulations regarding allowable noise levels have been promulgated for the safety and well being of humans. None of the existing regulations apply to effects of noise on wildlife, although some research has been conducted in this area (EPA 1971, Effects of noise on wildlife and other animals, Memphis State University). The objectives of the environmental noise program are to:

- Provide a data base on relative noise levels at various distances from sources on the tract

- Provide data for use by wildlife biologists in assessing the overall impacts of tract development on wildlife behavior and use of the study area.

2. Methods

In order to acquire the necessary noise level measurements, sound level readings are taken once each quarter at strategic monitoring sites around the mine development area. During the period of study, two noise surveys were made. Noise measurements were taken at 16 monitoring sites on August 20 and November 27. The monitoring sites were arranged in a configuration of concentric circles at various distances from the area of mine activity out to the borders of Tract C-a, as illustrated in Environmental Monitoring Sites Map 1--Physical (In map pocket) and described in Table 2-40. One other reading was taken in close proximity to the headframe for an indication of highest noise production.

Table 2-40. Locations of Environmental Noise Monitoring Sites, Tract C-a

Site Number	Locations/Descriptions
1	Top of knoll N.E. of Hunting Camp, E. of road down to Corral Gulch
2	South side of site access road, 20 ft S.W. of "Hill" signs
3	N.E. corner of intersection of Airplane Ridge Road and tank access road
4	South side of Corral Gulch Road at fence corner slightly past power line
5	100 ft S.E. from well CE-707, on line between survey point and Headframe
6	Northwest of Well TO-2 outside of fence, 10 ft W. of survey point
7	North side of Corral Gulch Road at Well G-S 4-5 on top of road cut
8	West side of Wolf Ridge road on small knoll directly across from entrance to Well G-S 6 and trailer camp
9	North side of fenced area at Well TO-1 near entrance
10	South side of Box Elder Gulch Road at N.E. fence corners for Well AM-3
11	North side of Corral Gulch Road at turn-around area, across from U.S.G.S. stream gauging station
12	South side of road to Met. Site #1, 0.1 mile from power line crossing and S.W. corner of well G-S 1
13	North side of Wolf Ridge Road, N.E. corner of road to Well G-S 10
14	South side of Wolf Ridge Road at Tract C-a boundary line
15	East side of road, 0.15 mile north of Met. Site #2 access road
16	North of County Road 24 at intersection of Wolf Ridge Road
A	Approximately 30 ft east of main shaft Headframe

The methods followed in the collection of noise data were described in RBOSC MDP Monitoring Report 3 and are not repeated herein.

3. Results and Discussion

Sound level readings taken during the two surveys are shown in Tables 2-41 and 2-42. The highest average decibel level was 79 dBA in the August survey and 75 dBA in the November survey. Both of these readings were obtained at the monitoring site near the headframe. Background noise levels were on the order of 25-30 dBA and were reached when readings were taken at distances greater than about one mile from mining activities. These same general decibel levels were found in readings taken near the site boundaries. Exceptions to background noise were noted when there was excess wind noise, aircraft passing overhead, vehicular traffic in the area or some other activity (e.g. drilling) near the monitoring site.

Noise levels taken during these two surveys were generally comparable to those taken during in the February and May 1979 surveys (RBOSC MDP Monitoring Report 4), and the August and October 1978 surveys (RBOSC MDP Monitoring Report 3). Higher noise levels measured in January and March 1978, (RBOSC MDP Monitoring Report 2) were probably due to differences in wind speeds and locations of the monitoring sites.

The potential for wildlife disturbances due to noise of this magnitude is anticipated to be small.

Table 2-41. Environmental Sound Level Measurements, Tract C-a, August 20, 1979

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level dBA Range	Sound level dBA Average	Remarks
A	8:03	0-3/SW	76-80	75-78	76-78	76-77	76-78	75-80	77	Job noise
1	8:10	Calm	48-49	46-49	45-47	44-46	43-45	43-49	46	Job noise
2	9:22	3-5/SW	47-62	43-53	44-50	42-52	45-65	42-65	50	Vehicle, job noise
3	9:38	5-8/SW	44-48	46-59	42-44	43-51	47-53	42-59	48	Wind, heavy equipment noise
4	8:49	3-5/SW	31-33	29-33	29-31	31-36	29-31	29-36	31	Wind, job noise
5	8:32	8-15/SW	31-49	32-49	30-52	36-50	34-52	30-52	42	Wind noise
6	8:24	5-8/SW	68-69	68-69	68-69	68-69	68-69	68-69	68	SIR pump noise
7	9:09	3-5/SW	42-47	44-48	40-48	39-45	42-47	39-48	44	Wind, job noise
8	10:02	3-15/SW	Wind noise too variable for reading: estimated 35-55 dBA for 8-20 second readings							
9	9:38	5-8/SW	26-40	30-49	26-38	25-32	23-26	23-49	32	Wind noise
10	9:49	5-10/SW	25-39	24-40	26-32	24-34	25-34	24-40	30	Wind noise
11	8:58	3-5/SW	26-36	25-35	25-40	26-40	26-32	25-40	31	Wind, Munson Well flare noise
12	8:39	8-10/SW	28-46	28-49	31-41	33-52	48-56	28-56	41	Wind, airplane noise
13	10:10	3-8/SW	28-39	32-40	32-40	28-39	28-33	28-40	34	Wind, airplane noise
14	10:17	5-15/SW	Wind noise too variable for reading: estimated 25-55 dBA for 8-20 second readings							
15	10:30	8-15/SW	28-48	27-45	26-32	27-40	34-45	26-48	35	Wind noise
16	9:14	3-8/SW	34-40	34-42	34-42	34-50	40-65	34-65	42	Wind, vehicle noise
A	10:50	3-15/SW	78-80	78-80	79-80	79-80	78-80	78-80	79	Wind, job noise

Table 2-42. Environmental Sound Level Measurements, Tract C-a, November 27, 1979

Site	Time	Wind	Sound Level Measurements (dBA, Slow Response) (20 sec range) 1	2	3	4	5	Sound Level dBA Range	Sound level dBA Average	Remarks
A	8:41	0-3/SSW	74-79	74-76	74-76	74-75	74-75	74-79	75	Process plant vents
1	8:49	0-3/SSW	31-35	31-35	34-36	36-37	37-38	31-38	35	Truck near Visitor's Center
2	12:01	5-12/SW	37-48	47-59	42-82	46-51	39-46	37-82	50	Job site, wind, vehicle noise
3	11:51	3-8/SW	35-44	34-47	34-49	33-46	33-44	33-49	40	Job site, wind noise
4	9:51	5-8/SW	30-42	29-40	38-46	32-41	32-48	29-48	38	Wind, airplane noise
5	9:21	3-8/SW	24-36	36-43	31-40	28-40	29-39	24-43	35	Wind, airplane noise
6	9:39	3-5/SW	22-29	21-32	21-23	21-38	22-31	21-38	26	Wind noise
7	10:12	5-8/SW	34-47	39-46	45-58	40-51	45-59	34-59	46	Wind, airplane noise
8	10:27	5-8/SW	39-49	35-58	36-50	33-49	32-49	32-58	43	Wind
9	11:23	3-15/SW	30-46	30-42	30-46	23-39	24-40	23-46	35	Wind, human activity noise
10	11:31	3-15/SW	29-50	28-42	28-48	28-49	31-48	28-50	38	Wind noise
11	9:59	5-8/SW	21-25	21-39	21-40	21-34	22-44	21-44	29	Wind noise
12	9:11	3-5/SW	45-52	36-44	26-37	26-39	25-36	25-52	37	Wind, airplane noise
13	10:37	3-12/SW	32-58	30-50	32-50	25-40	22-29	22-58	37	Wind noise
14	10:47	3-15/SW	25-49	45-50	25-50	22-38	22-47	22-50	37	Wind noise
15	10:56	3-12/SW	24-40	27-47	29-40	30-48	25-33	24-48	34	Wind noise
16	10:20	3-8/SW	45-61	42-48	42-55	45-51	42-58	42-61	49	Wind, vehicle noise
A	12:10	5-12/SW	74-81	75-81	70-77	72-75	70-75	70-81	75	Process plant vents, truck noise

2.7 SUMMARY

Both air quality and meteorological data were collected during the six-month reporting period. One unusual event occurred--the installation of an underground pipeline immediately adjacent to the Monitoring Site 1. At the peak of the construction activity, the primary 24-hr National Ambient Air Quality Standard (NAAQS) for total suspended particulates was exceeded once at the site. Ironically, this activity, which was unrelated to the development of Tract C-a, resulted in the highest measurement of total suspended particulates in four years of monitoring at the three main sites (303 $\mu g/m^3$).

The continuous monitoring system recorded only a very small number of events during which the concentrations of NO, NO_x, SO_2, H_2S, and CO were above the threshold of detection. Most of the time only ozone and total suspended particulates had concentrations above the threshold of detection.

Analysis of the four years of ozone data has shown that a diurnal cycle of relatively high ozone concentrations during the day and relatively low ozone concentrations at night is one of the most striking aspects of the data. This cycle has a much greater magnitude at Site 3. Review of the data indicates that the mechanism for this phenomenon is a nocturnal inversion which commonly develops over the gulch where Site 3 is located. This inversion effectively isolates the site from the relatively ozone-rich air present above the lowest boundary layer. After the inversion forms, typically around sunset, much of the ozone remaining in the ambient air trapped within the gulch is destroyed during the night by surface reactions. The breakup of the nocturnal inversion shortly after sunrise allows replenishment of the ozone in the gulch from upper levels. At Site 1, the diurnal cycle is greatly reduced because the location near the top of a hill is not conducive to the formation of a nocturnal inversion.

This hypothesized mechanism explains most of the observed variations in the local ozone concentrations, with the exception of the annual summer peak commonly found at many rural sites. There is no evidence of local photochemical production from either natural or anthropogenic sources. Thus, tract development to date appears to have had no effect on the ambient ozone levels.

Ozone concentrations do occasionally reach or exceed 0.080 ppm, primarily during the summer, but have never been recorded at levels approaching the NAAQS for oxidants (0.12 ppm). Concentrations comparable to those measured at Tract C-a have been found at many rural sites throughout the United States. The exact source of these relatively high ozone levels is currently the subject of active research.

The only verifiable air quality impact of tract development to date is the increase in particulate concentrations. The 24-hour secondary NAAQS for particulates was exceeded once at Site 3 (the treatment site downwind from the main tract development area) during the current year. However, a stepwise multiple regression analysis showed that the high particulate levels at Site 3 were more closely associated with meteorological conditions (high temperatures and low precipitation) rather than any measure of tract activity.

Several statistical analyses were performed on the particulate data sets, including correlations, multiple regressions, stepwise multiple regressions, and analysis of variance. It was found that the particulate concentrations measured at the tract could be divided into two periods with minimum overlap: 1) the winter season (the period with a semi-permanent snow cover), and 2) the summer season (the period with no snow cover). The statistical analyses were carried out on the winter, summer, and combined yearly data sets.

The correlation analysis showed that Sites 1 and 2 (the control sites generally upwind of the main development area) were the most highly correlated ($r = 0.84$ for the current year), whereas Sites 1 and 3 were the most weakly correlated ($r = .62$). There was little seasonal effect on the corrections.

The multiple regressions showed that approximately two-thirds of the variation in particulate concentrations could be explained by a combination of meteorological and site activity variables. Stepwise regressions indicated that, for the summer and combined data sets, the important factors in explaining the variation in particulate concentrations at Sites 1 and 2 were meteorological variables (i.e., precipitation, wind speed, and temperature). None of the site activity variables made significant contributions to the regression equations for these data sets.

At Site 3, an indicator of development activity was a significant variable in the regression, but it ranked no higher than third in importance of explaining the variation in particulate concentrations. Thus, development activity apparently had an impact on particulate concentrations only at Site 3 in the summer and yearly data sets. The regressions on the winter data set generally were not as successful in explaining the variation in particulate concentrations. This is probably due to the lower particulate levels and the much lower variation, which decreases the reliability of the regression analysis.

Comparison of the meteorological data set for the current year with the previous year's data set has revealed that the meteorology is very similar. The only exception is precipitation which, at 14 to 15 inches (the best estimate based on eight precipitation gauges), is the highest of the four years on record. The temperature range of 60 C (-30 C to +30 C) found during the current year is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of only 37 mph at the 10-m level. After four years of monitoring, RBOSC is beginning to develop a reasonable climatological record, although no long-term means can yet be determined.

The 1979 visibility program did not indicate any change in visual ranges in the Piceance Creek Basin. The mean annual visual range for 1979 was 80 miles, compared to 79 miles during the two previous monitoring years, 1978 and 1975-76. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range of 154 miles, measured during the three years of monitoring, occurred in 1979. Visual ranges near 150 miles were also recorded during the two earlier years of monitoring. This value approaches the theoretical limit of visual range in the atmosphere (200 miles).

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from 25 to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 77 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

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SECTION 3
TERRESTRIAL STUDIES

The Terrestrial Studies MDP Monitoring Program is designed to detect and evaluate those impacts affecting the vegetation or faunal components of the terrestrial ecosystems on or near RBOSC Tract C-a.

The Tract C-a terrestrial studies are geared to seasonal cycles of the ecosystem components. Therefore sampling is conducted during those seasons when the appropriate measurements can be made. The study period reported herein is December 1978 through November 1979. Vegetation mapping and stress based on color infrared (CIR) photography, phytosociology, range productivity and utilization, browse condition and utilization, small mammal, avifauna, mule deer, and feral horse studies are reported in this report. Opportunistic observations of important events and unscheduled special studies are included in MDP monitoring reports as they occur.

The terrestrial monitoring program is based on an assessment of current knowledge of MDP mining operations. Because this is a prototype operation, new information may become available which requires a modification of the outlined program. Therefore, this monitoring program should be viewed as a flexible one which may change as engineering design is refined and as additional ecological data are obtained.

3.1 VEGETATION, RANGE, AND BROWSE

A. Vegetation Mapping and Stress

1. Objectives

Construction and operation of Tract C-a may affect the local distribution and condition of vegetation types. The vegetation studies are designed to monitor the distribution of vegetation on Tract C-a and adjacent areas to determine large-scale changes resulting from MDP development, to identify stress conditions, and to document changes over time in the plant communities. Documentation of plant community distribution and condition is accomplished via color and CIR aerial photography.

2. Methods

Color and CIR aerial photographic studies follow methods detailed in RBOSC MDP Reports 1 and 4. The areas photographed during June 1979 are delineated on the Environmental Monitoring Sites Map 2 - Ecological (in map pocket). Color balance on the 1979 CIR photographs was matched to that of the 1974 photographs so that direct comparisons would be more meaningful.

3. Results and Discussion

Detailed study of 1974 CIR prints has shown that a number of areas in the Tract C-a vicinity support vegetation indicative of moderate soil moisture. When soil moisture is relatively abundant, mesic, herbaceous plant species are favored. This vegetation can be identified on CIR photographs by the presence of red tones. Areas enclosed by lines on Figure 3-1 represent a preliminary determination of "moist pockets" identified from 1974 photographs. Dashed lines indicate potential "moist pockets" which require further study. When 1974 and 1979 CIR prints were compared, the moist areas identified in 1974 also were evident in 1979 photographs. Some increases in moisture balance were noted between years and these are shown as shaded areas on Figure 3-1. Moisture changes were most prominent in valley bottoms, and in some instances correspond

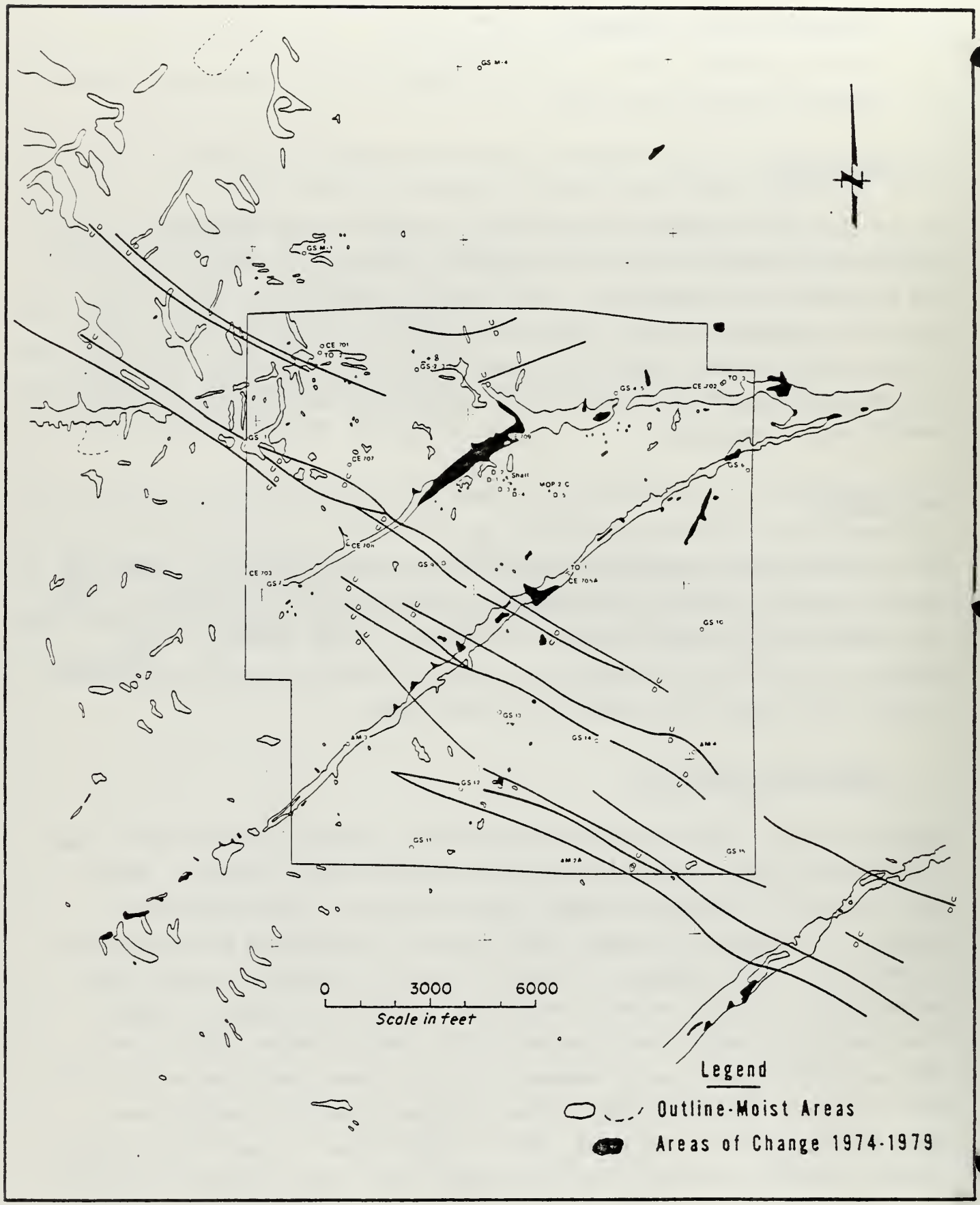

Figure 3-1. Variations in Moisture Regime Based on Color Infrared Photography of Tract C-a and Vicinity (prepared by R. A. Hodgson)

to springs or seeps. Moisture increased slightly to the SW of G-S 6, near the confluence of Rinky Dink and Box Elder Gulches in 1979. Increases such as this may be related to short-term variations in local moisture regimes, such as heavy winter snowfall or large volumes of spring rainfall. However, reinjection at G-S 6 may also be augmenting flow in existing seeps in this area.

A second area of note is the portion of Corral Gulch located approximately .75 miles east of Meteorological Monitoring Site 3. At this point in the valley, the stream changes from channelized to wide-spreading flow. Alteration in the flow pattern appears to be a natural occurrence and may be related to a minor change in gradient. This pattern is clearly evident on 1974, 1978 and 1979 aerial photographs. During periods of peak runoff or during episodes of heavy rainfall, it is likely that this wide-spreading flow pattern results in the saturation of alluvium across much of the valley bottom.

Sagebrush can exist under conditions of intermittent saturation of the root zone, but may succumb when periods of saturation are frequent or continuous. Examination of color and CIR photographs taken in 1974 indicates that some patches of sagebrush within the aforementioned area were dead or dying at that time. Dead sagebrush in the area has become increasingly evident during the 1979 growing season. It is possible that discharge of water from Tract C-a into Corral Gulch typifies natural, high runoff periods, and consequently, results in saturation of the alluvium on a more regular basis. Reinjection activities also may influence moisture balance in the area, as evidenced by the appearance of Miller Spring, which is located a short distance up-gradient from the affected area. If this is the case, development on Tract C-a may be facilitating an increase in the natural rate of community succession. Expected changes would be reduction in sagebrush and concomitant increases in grass communities.

The largest area of change noted on Tract C-a was located in Corral Gulch to the NW of the mine site. Increased moisture in this area may be related to mine dewatering discharge. Although discharge is directed into the channelized portion of the creek, prolonged and/or increased flow may affect moisture in the alluvium adjacent to the point of discharge. This would account for the size of the affected area. Alterations to plant communities have not yet been observed in this area.

B. Phytosociological Studies

1. Objectives

The objective of the phytosociological studies is to monitor species composition and coverage in the major vegetation types expected to be affected by Tract C-a development. These studies provide quantitative data which complement information on distribution of major habitat types, and provide continuity with similar data collected during the baseline period.

2. Methods

Phytosociological studies are conducted in pinyon-juniper and sagebrush vegetation types in a control site south of Tract C-a (Location 6) and in a treatment site on Airplane Ridge (Location 5) (see Environmental Monitoring Sites Map 2 -- Ecological in map pocket). These sites correspond to the sampling locations for the soil, small mammal, and avifauna studies. The "treatment" defined as part of the monitoring program included potential effects of air pollutant emissions and other associated impacts. Potential impacts will be assessed after the retorts are burned. As development progresses the treatment site will be moved as necessary.

Phytosociological sampling is conducted in May-June once every three years in a specific vegetation type on a rotation basis. During the initial sampling period in each type, density and cover of woody species and herbaceous cover are determined; thereafter only herbaceous cover will be measured. Sampling began in June 1979 in the pinyon-juniper habitat type.

Density of woody species is determined in five permanently established belt transects (100 x 6 m). This modified line-strip method was used to determine density of woody species during the baseline program (RBOSC 1975). In addition, a line-transect (100 m length) was established in each of the five belt transects (total 500 m) to determine cover of each woody species.

Herbaceous cover is measured within 20-1 x 1 m plots permanently established within each belt transect (total 100 plots per vegetation type).

At each control and treatment site within each vegetation type, photoplots are established at each belt transect to monitor changes in the vegetation. Photos are taken annually (during June) from permanently marked locations.

Cover and density data are entered and stored on 9-track, 800 bpi magnetic tape and all data analyses are performed by computer. Quality assurance procedures are employed to ensure data validity.

Analyses for phytosociological studies are designed to test the following hypothesis:

H_o: There is no significant difference in herbaceous cover within a vegetation type before and during modular development.

The herbaceous cover data are analyzed by the following Analysis of Variance (ANOVA) to compare pre-development conditions with those during development.

Source of Variation	Degrees of Freedom	F-Test
A. Location a=2	a-1 = 1	A/D
B. Phase b=2	b-1 = 1	B/D
C. Location x Phase	(a-1)(b-1) = 1	C/D
D. Error (n=100)	ab(n-1) = 396	
Total	abn-1 = 399	

This two-way ANOVA design is used to determine the differences in herbaceous cover between two locations (main effect A) and between phases (before versus during development, main effect B). The interaction effect (C) will test location x phase interactions. If the interaction effect is significant, then multiple range tests will be performed to determine the source of the interaction.

Because the woody species data are only collected once, these data are not amenable to ANOVA analyses. These data will serve as additional "baseline" information for the control and treatment sampling sites and will be used in

the interactions analyses with the wildlife data. If impacts are detected by the photoplot or vegetation distribution monitoring programs, then subsequent woody species sampling programs will be initiated.

3. Results and Discussion

Transects were sampled in the pinyon-juniper habitat type between June 16 and June 29, 1979. Photoplots for all transects were established from June 27 - 29, 1979. Coverage and density for species encountered along the transects are summarized on Tables 3-1 and 3-2, and raw data are presented in Appendix 3-1.1.

Average coverage of trees and shrubs was 51.6 percent in the control area (5) and 58.0 percent in the treatment area (6) (Table 3-1). Pinyon pine accounted for the majority of coverage, averaging 36.2 and 31.4 percent in the respective areas. Juniper coverage averaged 12.4 and 19.0 percent in the respective sites. Serviceberry and sagebrush were prevalent in the two areas but had relatively low coverage as compared with either pinyon or juniper.

Density of sagebrush averaged 1073 stems per hectare in the control area and 1666 stems per hectare in the treatment area. Serviceberry, rabbitbrush, and bitterbrush also exhibited relatively high densities (Table 3-1). The density of snowberry varied markedly between sites, averaging 860 stems in the treatment and 43 stems per hectare in the control area. Density of pinyon pine was 33 percent greater in the treatment area (1143 stems/ha), whereas juniper density (576 stems/ha) was 10 percent lower there than in the control area.

Grass species averaged 7.3 percent coverage in the control area and 8.8 percent in the treatment area (Table 3-2). Regardless of variations in species presence and/or abundance, there was little difference in total grass coverage between sites. Poa sp. was the most abundant species in the control area (average, 3.2% coverage) whereas Oryzopsis was the dominant grass in the treatment area (average, 4.6% coverage).

Table 3-1. Coverage and Density of Tree and Shrub Species Encountered on Transects in the Pinyon-Juniper Habitat Type for Control Area 6 and Treatment Area 5 During 1979, Tract C-a

Species	Control Area (6)				Treatment Area (5)			
	Average Density (Stems/ha)	Range (Stems/ha)	Average Cover (%)	Range (%)	Average Density (Stems/ha)	Range (Stems/ha)	Average Cover (%)	Range (%)
Shrubs								
Amelanchier utahensis	157	0 - 650	0.3	0.0 - 1.5	856	0 - 1949	3.3	0.0 - 9.8
Artemisia frigida	ND	ND	ND	ND	13	0 - 67	ND	ND
Artemisia tridentata	1073	133 - 2632	2.3	0.0 - 3.2	1666	133 - 3149	2.5	0.6 - 4.1
Ceratoides lanata	23	0 - 117	0.1	0.0 - 0.5	67	0 - 233	0.04	0.0 - 0.2
Cercocarpus montanus	ND	ND	ND	ND	140	0 - 560	0.3	0.0 - 0.4
Chrysothamnus nauseosus	0.4	0 - 33	ND	ND	97	17 - 366	0.02	0.0 - 0.1
Chrysothamnus viscidiflorus	313	0 - 1333	0.1	0.0 - 0.4	220	0 - 733	0.1	0.0 - 0.4
Purshia tridentata	243	17 - 716	0.2	0.0 - 1.0	210	0 - 566	0.1	0.0 - 0.6
Symphoricarpos oreophilus	43	0 - 150	ND	ND	860	150 - 1716	1.2	0.0 - 4.8
	Total Shrub Coverage[1]		3.0				7.6	
Trees								
Juniperus osteosperma	640	450 - 866	12.4	4.9 - 18.7	576	466 - 716	19.0	11.9 - 24.2
Pinus edulis	780	367 - 966	36.2	11.3 - 55.4	1143	766 - 1583	31.4	14.5 - 39.9
	Total Tree Coverage[1]		48.6				50.4	
Total Coverage of Woody Species			51.6				58.0	

[1] Sum of average coverages for species occurring on line transects

ND = No Data

Table 3-2. Coverage of Grass and Forb Species Encountered on Transects in the Pinyon-Juniper Habitat Type for Control Area 6 and Treatment Area 5 during 1979, Tract C-a

Species	Control Area (6) Average Cover (%)	Control Area (6) Range (%)	Treatment Area (5) Average Cover (%)	Treatment Area (5) Range (%)
Grasses				
Agropyron sp.	0.1	0.0 - 0.30	0.7	0.0 - 1.90
Agropyron trichophorum	0.2	0.0 - 0.80	ND	ND
Bromus sp.	0.01	0.0 - 0.05	ND	ND
Bromus tectorum	0.2	0.0 - 0.65	0.02	0.0 - 0.05
Carex geyeri	ND	ND	0.6	0.0 - 1.80
Grass sp.	1.2	0.0 - 4.40	0.5	0.0 - 1.50
Oryzopsis hymenoides	0.5	0.0 - 1.25	4.6	0.0 - 9.20
Poa fendleriana	0.4	0.0 - 2.0	1.5	0.0 - 3.35
Poa sp.	3.2	0.1 - 6.75	ND	ND
Sitanion hystrix	1.0	0.3 - 2.05	0.4	0.0 - 1.75
Stipa comata	0.4	0.0 - 2.05	0.1	0.0 - 0.30
Stipa sp.	0.1	0.0 - 0.55	0.4	0.0 - 1.90
Total Grass Coverage[1/]	7.3		8.8	
Forbs				
Achillea lanulosa	0.03	0.0 - 0.10	ND	ND
Agoseris glauca	0.4	0.0 - 1.05	0.1	0.0 - 0.40
Androsace septentrionalis	ND	ND	0.02	0.0 - 0.10
Antennaria pulcherrima	ND	ND	0.05	0.0 - 0.15
Antennaria sp.	0.01	0.0 - 0.05	ND	ND
Arabis sp.	0.01	0.0 - 0.05	ND	ND
Astragalus diversifolius	ND	ND	0.1	0.0 - 0.30
Astragalus sp.	0.01	0.0 - 0.05	0.04	0.0 - 0.10
Balsamorhiza sagittata	0.6	0.0 - 2.25	1.2	0.0 - 4.25
Boraginaceae sp.	0.3	0.0 - 1.5	ND	ND

Table 3-2. (continued)

Species	Control Area (6) Average Cover (%)	Control Area (6) Range (%)	Treatment Area (5) Average Cover (%)	Treatment Area (5) Range (%)
Chaenactis douglasii	0.01	0.0 - 0.05	ND	ND
Chenopodium sp.	0.4	0.0 - 1.8	0.2	0.0 - 0.45
Collinsia parviflora	0.4	0.0 - 1.15	0.1	0.0 - 0.55
Cruciferae sp.	0.02	0.0 - 0.1	0.05	0.0 - 0.15
Cryptantha sericea	0.6	0.15- 1.45	0.9	0.1 - 2.25
Descurania richardsonii	ND	ND	0.4	0.0 - 1.55
Erigeron eatonii	0.05	0.0 - 0.25	0.1	0.0 - 0.40
Eriogonum umbellatum	0.01	0.0 - 0.05	0.1	0.0 - 0.35
Haplopappus acaulis	0.01	0.0 - 0.05	ND	ND
Haplopappus nuttallii	0.01	0.0 - 0.05	ND	ND
Lithospernum ruderale	ND	ND	1.0	0.0 - 2.75
Lomatium juniperinum	0.2	0.0 - 0.85	ND	ND
Lupinus sp.	0.5	0.0 - 1.80	ND	ND
Opuntia sp.	0.5	0.0 - 1.0	0.2	0.0 - 0.5
Penstemon caespitosus	0.02	0.0 - 0.10	0.3	0.0 - 1.00
Phlox hoodii	0.4	0.0 - 1.0	0.3	0.0 - 0.65
Phlox longifolia	0.4	0.0 - 0.85	0.03	0.0 - 0.10
Phlox sp.	ND	ND	0.02	0.0 - 0.10
Physaria floribunda	0.01	0.0 - 0.5	0.1	0.0 - 0.15
Sisymbrium altissimum	0.2	0.0 - 0.75	ND	ND
Sisymbrium linifolium	0.02	0.0 - 0.1	ND	ND
Sphaeralcea coccinea	0.4	0.0 - 1.0	0.3	0.0 - 0.8
Tragopogon sp.	0.04	0.0 - 0.2	ND	ND
Trifolium gymnocarpon	0.3	0.2 - 0.3	0.2	0.0 - 0.30
Unknown composite	0.04	0.0 - 0.05	0.03	0.0 - 0.15
Unknown forb	0.5	0.05- 0.95	0.2	0.0 - 0.50
Total Forb Coverage[1/]	6.4		6.0	
Total Herbaceous Coverage	13.7		14.8	

[1/] Sum of average coverages for species occuring within sample plots.

ND = No Data

Forb species encountered in the control area resulted in an average cover of 6.4 percent (Table 3-2). Of the thirty species identified, no single species had a mean coverage greater than 0.6 percent. Cryptantha, Balsamorhiza, Lupinus, Opuntia, and Phlox were among the more prevalent forb species, and accounted for 42 percent of the total forb coverage.

Total forb coverage in the treatment area averaged 6.0 percent. Balsamorhiza, Lithospermum, Cryptantha, and Descurania were the most prevalent species, averaging 1.2, 1.0, 0.9, and 0.4 percent coverage respectively (Table 3-2). These four species accounted for 60.5 percent of the total forb coverage. Species richness was lower in the treatment area than in the control area (24 vs. 30 species).

Total herbaceous coverage was 13.7 percent in the control area and 14.8 percent in the treatment area. Analysis of variance indicated that there was no significant difference in herbaceous coverage between the two study sites (Appendix 3-1.2). Tests for equality of two percentages (Sokal and Rohlf 1969) were performed on percentages for total herbaceous coverage, as well as those for total grass coverage and total forb coverage. These tests confirmed that there were no significant differences between years for any of these parameters.

C. Range Productivity and Utilization

1. Objectives

MDP activities on Tract C-a may affect range conditions on and near the tract by altering use patterns of deer, cattle, and feral horse populations and increasing grazing pressure. The range studies are designed to provide information which can be used to compare range productivity and utilization before and during modular development. Because activities associated with tract development are confined primarily to the mine process area, impacts on range conditions are projected to be localized. Therefore, range studies focus on areas of Tract C-a that are adjacent to MDP activities, and that were previously used for grazing.

2. Methods

The basic methods followed for collection of range data were described in RBOSC MDP Monitoring Reports, 1, 2, 3, and 4, but were modified slightly during the 1979 sampling period. Plots were sampled using a sampling loop 1 sq m in area. Clipped samples were bagged and field weights for samples were determined using Pesola spring balances accurate to 0.5 g. Samples were oven-dried for 24 hours at 105 C, and dry weights were ascertained using an Ohaus model 1650 Dial-O-Gram balance accurate to 0.1 g.

The range productivity data are analyzed by the following two-way ANOVA to compare pre-development conditions with those during development.

	Source of Variation	Degrees of Freedom	F-Test
A.	Phase a = 2	a-1 = 1	A/D
B.	Protected vs. Unprotected Plots b = 2	b-1 = 1	B/D
C.	Phase x Plots	(a-1)(b-1) = 1	C/D
D.	Error (n = 50)	ab(n-1) = 196	
	Total	abn-1 = 199	

3. Results and Discussion

The 30 range transects were sampled September 25 through October 10, 1979. These data are presented in Appendix 3-1.3, and are summarized in Table 3-3.

a. Mixed Brush - Average production in the mixed brush habitat type was 209 kg/ha during 1979. Grasses accounted for 109 kg/ha and forbs 100 kg/ha (Tables 3-3, 3-4). Agropyron (wheatgrass) species, Poa (bluegrass) species, and Oryzopsis hymenoides (indian ricegrass) were the dominant grasses, comprising 92 percent of biomass in protected (caged) plots and 91 percent of the production in unprotected (no cages) plots. Comandra, Hedysarum, and Eriogonum species were the most important producers among the thirty-eight forb species encountered. These species accounted for 59 percent of production in caged plots and 42 percent in uncaged plots.

Table 3-3. Range Production (dry weight, kg/ha) of Species Encountered in Caged and Uncaged Plots within Three Vegetation Types During 1979, Tract C-a

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Grasses						
Agropyron dasystachyum					3.9	0.5
Agropyson sp.	62.0	37.7	12.7	7.6	80.8	25.0
Bromus tectorum	0.1	0.4	0.5	0.4	11.0	18.0
Carex sp.	0.6	3.3	1.4	1.5		
Koeleria gracilis	7.2	2.2	0.5		2.0	1.3
Oryzopsis hymenoides	48.3	21.2	8.4	2.5	16.4	2.5
Poa sp.	17.9	12.3	8.7	8.0	11.6	10.2
Sitanion hystrix		0.4	0.7	0.4	7.7	5.8
Stipa sp.	3.9	1.1	0.1	0.2	1.3	3.7
Unknown grass				0.7		0.5
Total grasses (kg/ha)	140.0	78.6	33.0	21.3	134.7	67.5
Average Production (kg/ha)	109.3		27.1		101.1	
Percent Utilization	43.8		35.4		49.9	
Forbs						
Achillea lanulosa	0.2	0.5				
Agoseris sp.		0.1	0.5		2.2	0.9
Antennaria sp.	1.6	1.3			0.6	0.5
Arenaria fendleri			0.3	0.2		
Artemisia ludoviciana	0.2	0.9				
Astragalus chamaeleuce	0.1	0.2				

Table 3-3. (Continued)

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Forbs (Continued)						
Astragalus convallatius	2.3	0.4	0.2			
Astragalus diversifolius	0.7		0.2		1.2	1.2
Astragalus sp.			0.1	0.1	0.8	0.1
Balsamorhiza sagittata		4.9	0.2	3.9	7.1	0.6
Castilleja sp.	0.5					
Chenopodium album			2.1	0.1	0.3	0.6
Chenopodium sp.	0.2				0.1	0.2
Cleome serrulata						4.1
Comandra umbellatum	11.2	13.9			2.9	0.9
Cruciferae sp.	1.2	0.2	0.5		0.3	1.0
Cryptantha sericea	1.7	2.0	1.5	2.2	2.0	2.2
Cryptantha sp.	0.1	0.2				
Eriogonum densum	7.8				0.5	
Eriogonum sp.	1.1	0.3	4.2	3.6		
Eriogonum umbellatum	17.4	17.5	0.2	0.4		0.4
Haplopappus nuttallii	4.1	3.8	3.4	4.1	1.3	0.9
Hedysarum boreale	26.7	5.9			2.5	0.2
Heterotheca villosa	2.5	1.9	0.2	0.1	1.3	0.8
Heuchera parvilflora	0.9					
Hymenoxys acaulis	0.2	0.8				
Ipomopsis sp.	0.6					
Linum lewisii	0.9	0.5			0.1	0.3

Table 3-3. (Continued)

Species	Mixed Brush		Pinyon-Juniper		Upland Sagebrush	
	Caged	Uncaged	Caged	Uncaged	Caged	Uncaged
Forbs (Continued)						
Lupine sp.	4.3	11.8			6.5	6.7
Mahonia repens	5.3	5.5		0.0		
Pachistima myrsinites		1.3				
Penstemon caespitosus	4.5	2.3	0.7		0.8	1.4
Penstemon sp.		0.4				0.1
Phlox longifolia	4.3	2.4	0.1	0.1	1.9	2.5
Phlox multiflora		1.9				
Physaria floribunda	0.9	0.5	0.3		0.2	0.1
Salsola kali		0.1				
Senecio multilobatus	0.2	0.7			0.6	
Senecio sp.		0.1				0.2
Sphaeralcea coccinea	4.7	0.9	1.2	0.3	2.2	2.4
Unknown composite	0.7	6.4	0.9	0.3	2.5	0.3
Unknown forb	2.2	0.8	0.6	0.7	2.4	0.5
Total forbs (kg/ha)	109.3	90.4	17.4	16.1	40.3	29.1
Average Production (kg/ha)	99.8		16.8		34.7	
Percent Utilization	17.3		7.5		27.8	
Total Grasses and Forbs (kg/ha)	249.3	169.0	50.4	37.4	175.0	96.6
Average Production (kg/ha)	209.2		43.9		135.8	
Percent Utilization	32.2		25.8		45.0	

Table 3-4. Comparison of Range Production (dry weight, kg/ha) and Utilization (%) Estimates Obtained on and near Tract C-a, 1975 through 1979[1/]

Vegetation Type	Production (dry weight, kg/ha) 1975	1977	1978	1979	Utilization (%) 1975	1977	1978	1979
Mixed Brush								
Grasses		165	97	109		65	26	44
Forbs		110	111	100		47	29	17
Total	233	275	208	209	38	56[2/]	28[2/]	31[2/]
Pinyon-Juniper								
Grasses		66	27	27		50	48	35
Forbs		9	16	17		31	42	8
Total	113	75	43	44	32	41[2/]	45[2/]	21[2/]
Upland Sagebrush								
Grasses		107	79	101		58	39	50
Forbs		18	45	35		23	47	28
Total	302	125	124	136	8	41[2/]	43[2/]	39[2/]

[1/] The comparison is for the vegetation type in general. The same transects were not sampled during each period nor was the sample size equal.

[2/] An average of grass and forb utilization.

Production in the mixed brush habitat type was the highest of the three vegetation types sampled. Total production during the 1979 sample period was greater than during 1978, but lower than 1975 or 1977 production (Table 3-4). Production of forbs during 1977, 1978, and 1979 varied between a low of 100 kg/ha in 1979 to 111 kg/ha in 1978. Grass production was variable during the same three-year period. Production of grasses was highest in 1977 (165 kg/ha) and lowest in 1978 (97 kg/ha). Comparison of production between 1978 and 1979 indicated no significant differences between years (α= 0.05) (Table 3-5, Appendix 3-1.4).

Utilization of all species within the mixed brush habitat type averaged 31 percent during the 1979 sample period, and as such was lower than that occurring during 1975 and 1977, but slightly greater than the 28 percent utilization evidenced during 1978 (Table 3-4). A comparison of production for all species in caged versus uncaged plots during 1978 and 1979 indicated that protected plots had a significantly greater production than unprotected plots (Table 3-5) (α= 0.05). This difference is expected and represents the effects of grazing by wildlife and/or cattle on the unprotected plots. Grasses exhibited 44 percent use in 1979 whereas forbs had 17 percent use. A similar pattern was noted during 1977 when grass use (65 percent) exceeded that of forbs (47 percent). In 1978 use of forbs was slightly greater than that for grasses, 29 and 26 percent utilization respectively.

When viewed in relationship with previous years, the data for the mixed brush habitat suggest variability in both production and utilization. One can only speculate as to source of these differences. It is probable that some variation in production results from differences in available moisture between years. However, it is unclear whether variations in use pattern result from normal fluctuations in wildlife populations or to Tract activities. Continued monitoring of range production and utilization will help answer these questions.

b. Pinyon-Juniper - Average production of above-ground biomass in the pinyon-juniper habitat type was 44 percent, with 27 percent as grasses and 17 percent forbs (Table 3-3). As with the mixed brush type, wheatgrass, bluegrass, and Indian ricegrass species were the dominant grasses. In caged and uncaged

Table 3-5. Summary of ANOVA Results Comparing 1978 and 1979 Range Productivity, Tract C-a [1/]

Habitat Type	Source of Variation: Between Years F	Between Years PR>F [2/]	Caged vs. Uncaged F	Caged vs. Uncaged PR>F [2/]	Interaction F	Interaction PR>F [2/]
Mixed Brush	1.62	0.2043	9.44*	0.0024	0.16	0.6913
Pinyon-Juniper	2.57	0.1102	7.29*	0.0075	0.26	0.6081
Upland Sagebrush	5.54*	0.0196	22.20*	0.0001	1.74	0.1887

* ($\alpha = 0.05$)

[1/] Complete analyses are presented in Appendix 3-1.4.

[2/] PR>F represents the significance probability (α) associated with F.

plots these species accounted for respective biomass values of 90 and 85 percent of total grass production (Table 3-3). Chenopodium, Cryptantha, Eriogonum, and Haplopappus species were important components in both protected and unprotected plots. However, none of these species achieved the degree of dominance exhibited by individual species of the mixed brush habitat type.

Average production of both grasses and forbs was lower than in either the mixed brush or sagebrush type. Furthermore, production within the pinyon-juniper vegetation type has been variable between the four sampling years. A high of 114 kg/ha was recorded in 1975, and the lowest production (43 kg/ha) occurred in 1978. Total production during 1979 (44 kg/ha) was similar to that of the preceding year, but considerably lower than production during 1977 or 1975 (Table 3-4). A statistical comparison between 1978 and 1979 data indicates that there is no significant difference in total production for these years (Table 3-5, Appendix 3-1.4). Variations between 1979 and 1977 data are due primarily to an abundance of grasses produced in 1977. During 1977 forb production was 9 kg/ha, approximately one-half that recorded during 1979. Statistical comparisons for the early years are not appropriate because of variations in sample sites.

Forage use within the pinyon-juniper habitat type (average = 21 percent) was low during 1979. Utilization of grass species averaged 35 percent whereas forb use was 8 percent (Table 3-4). As expected, significant differences were noted for production in caged versus uncaged plots (Table 3-5) ($\alpha = 0.05$). Respective grass production in caged vs. uncaged plots during 1979 was 33 and 21 kg/ha, and that for forbs was 17 and 16 kg/ha (Table 3-3). These data suggest that differences in production may have resulted from the dominant use of graminoid species. When compared with the 1975, 1977, and 1978 collection periods, 1979 utilization was noticeably lower. It is evident that much of this difference is attributable to reduced forb use during 1979. Use of forbs during 1977 and 1978 averaged 31 and 42 percent respectively, whereas 1979 use was 8 percent. Data for 1977 and 1978 indicate that forb use was typically lower than that for grasses. This trend is reasonable because grasses are preferred forage species. Nevertheless, it is unclear why the decreased use of forbs in 1979 was proportionately larger than that for grasses.

As noted with data from the other habitats, production and utilization in the pinyon-juniper type vary between years. Higher values for productivity were noted during the first two years of study, and uniform production was evident in 1978 and 1979. Percentage utilization tended to be highest in 1977 and 1978, and somewhat lower during 1975 and 1979. With only four years of data available for comparison, definitive trends cannot be ascertained, nor is it possible to attribute these fluctuations to changes in wildlife populations or tract activities.

c. Upland Sagebrush - Average production in the upland sagebrush habitat was 136 kg/ha during 1979. Grasses accounted for 101 kg/ha, with wheatgrass species comprising 54 percent of the total production on all plots. Indian ricegrass and bluegrass species also continued to be important graminoid components. The sagebrush type differed from other habitats in that Bromus and Sitanion contributed considerable above-ground biomass (Table 3-3). These latter species are generally less palatable and may reduce prime forage production by competing for available nutrients and moisture. Production of forbs amounted to 35 kg/ha, or approximately 26 percent of the total. Species richness and production of forbs were greater than in pinyon-juniper, but lower than the mixed brush habitat type. Balsamorhiza, Comandra, Cryptantha, Lupinus, Phlox, and Sphaeralcea were among the more productive species.

Relative to other habitats sampled, the sagebrush type exhibited intermediate production values for 1979. Production between years varied from 124 kg/ha in 1978 to 302 kg/ha in 1975. Statistical comparisons between 1978 and 1979 data indicated significantly higher production for 1979 (Table 3-5, Appendix 3-1.4). In addition, production within caged plots was significantly greater than in unprotected plots in the upland sagebrush type for 1978 and 1979. Although direct comparisons with 1975 or 1977 data are not valid due to variations in sampling sites, it is evident that production vagaries among years are noteworthy. It is uncertain why large variations occur over a relatively short period (4 years). For whatever the reasons, naturally occurring perturbations in production make long-term predictions difficult, i.e. consider variations recorded for grasses and forbs within this vegetation type between sample years. Production of grass species during 1979 was 6 percent lower

than that of 1977, and 22 percent higher than production of 1978 (Table 3-4). Forbs exhibited an increase from 18 kg/ha in 1977 to 45 kg/ha in 1978, and decreased to 35 kg/ha in 1979.

Utilization of forage in the upland sagebrush vegetation type averaged 39 percent during 1979. Grasses were used at the 50 percent level whereas forb usage averaged 28 percent (Table 3-4). Use during 1977, 1978, and 1979 was consistent and ranged from 39 to 43 percent. However, the 8 percent utilization recorded during the 1975 sample period was noticeably lower. Although usage of grasses and forbs was similar for the 1977 and 1979 periods, utilization of grasses during 1978 was lower and utilization of forbs was higher than during the aforementioned periods. Variations such as these are consistent with fluctuations evidenced for both production and utilization in other vegetation types. As noted earlier, variations in production may result from normal variations in moisture between years. Utilization data for the upland sagebrush sites show little change within the MDP period. This may suggest that tract development is not influencing the pattern of utilization in the upland sagebrush vegetation type. However, further study is needed to determine the natural variability within ecosystems before such a hypothesis can be confirmed. At this time, data do not substantiate definite trends in either production or utilization.

D. Browse Condition and Utilization

1. Objectives

Tract C-a development may alter browse availability and consequently affect wildlife distribution in the vicinity. Browse condition and utilization studies are designed to provide information on use of important shrub species adjacent to Tract C-a development.

2. Methods

The methods followed for collection of browse data were patterned after those of Cole (1963) and were outlined in RBOSC MDP Monitoring Reports 1, 2, and 4.

Environmental Monitoring Sites Map 2 - Ecological (map pocket) illustrates the locations of 30 transects used for browse studies.

The browse utilization data collected in the mixed brush, pinyon-juniper, and sagebrush types are analyzed by the following one-way ANOVA, which is designed to test for significant differences in browse utilization of a specific plant species within a given vegetation type between phases of development.

	Source of Variation	Degrees of Freedom	F-Test
A.	Phase of development a = 2	a-1	A/B
B.	Number of individuals/species within 10 transects $b_i = x$	$a(b_i-1)$	B/C
C.	Error (n = 10)	$a(b_i)(n-1)$	
	Total	ab_in-1	

3. Results and Discussion

Data obtained during May 1979 are summarized in Table 3-6. The 30 transects sampled were the same as those studied during the 1978 sampling period. Raw data for 1979 studies were presented in RBOSC MDP Report 4, and the resultant computerized data set is listed in Appendix 3-1.5 of this report.

a. Mixed Brush - Of the five shrub species sampled in the mixed brush habitat type, mountain mahogany had the greatest utilization (35.4%) whereas snowberry had the lowest utilization (4.5%) (Table 3-6). Mountain mahogany exhibited a three-fold increase in utilization during the 1979 browse season over the 1978 season. In spite of this increase, mountain mahogany browse leader use would be termed "acceptable" by Cole (1963) for "average" winter conditions.

The browse condition rating for mountain mahogany was "poor" whereas the remaining species continued to be categorized as being in "good" condition (Cole 1963). These ratings are the same as those observed for the mixed brush habitat type during the 1978 season.

Table 3-6. Condition of Important Browse Species Sampled in Three Vegetation Types During May 1979 in the Vicinity of RBOSC Oil Shale Tract C-a

Habitat Type	Species	Number Plants Sampled	Average Util. (%)	Average Avail. (%)	Form Class (%)								Age Class (%)				Hedging Class (%)		
					1	2	3	4	5	6	7	8	Seedling	Young	Mature	Decadent	Light	Moderate	Severe
MB	Serviceberry	128	9.0	78.4	38	12	6	13	16	7	-	8	2	6	53	38	53	30	17
	Sagebrush	61	5.0	81.1	31	23	-	10	16	10	-	10	-	-	66	34	45	45	9
	Snowberry	41	4.5	62.9	34	2	-	27	22	5	5	5	2	10	34	54	64	31	5
	Mountain Mahogany	14	35.4	83.8	7	36	14	7	7	14	-	14	14	-	57	29	17	50	33
	Pinyon Pine	6	7.8	100.0	50	33	-	17	-	-	-	-	-	-	100	-	67	33	-
PJ	Sagebrush	103	11.7	68.9	15	12	7	15	17	22	-	13	1	-	41	58	32	33	34
	Pinyon Pine	50	6.5	65.2	28	8	10	20	12	-	20	2	6	6	80	8	61	29	10
	Juniper	37	0.1	42.8	24	-	-	24	16	3	19	14	-	3	73	24	75	22	3
	Bitterbrush	36	23.1	64.6	3	17	8	3	36	25	-	8	-	-	39	61	6	58	36
	Mountain Mahogany	17	55.9	69.5	-	-	12	-	6	82	-	-	-	-	65	35	-	-	100
	Snowberry	4	66.7	34.0	-	25	50	-	-	-	-	25	-	-	75	25	-	33	67
	Serviceberry	3	29.0	23.3	-	33	-	33	-	33	-	-	-	-	33	67	33	33	33
SB	Sagebrush	235	3.9	78.6	17	14	3	12	14	16	-	23	-	-	49	51	37	37	26
	Serviceberry	11	3.3	85.6	45	18	-	18	-	-	-	18	-	18	55	27	89	11	-
	Snowberry	4	0.0	28.8	-	-	25	-	75	-	-	-	-	-	25	75	-	75	25

MB = Mixed Brush
PJ = Pinyon-Juniper
SB = Sagebrush

Form Classes

1 All available, little or no hedging
2 All available, moderately hedged
3 All available, severely hedged
4 Partially available, little or no hedging
5 Partially available, moderately hedged
6 Partially available, severely hedged
7 Unavailable
8 Dead

When all species are considered, the weighted average percent utilization for the mixed brush type was slightly greater in 1979 than that for 1978 (Table 3-7). However, utilization for the mixed brush type has exhibited noticeable fluctuations among years.

Table 3-7. Comparison of Utilization (weighted average, in percent) in Three Vegetation Types During April 1976, May 1977, May 1978, and May 1979 on and Near Tract C-a[1/]

Vegetation Type	April 1976	May 1977	May 1978	May 1979
Mixed Brush	12	17	7	8
Pinyon-Juniper	27	24	31	15
Upland Sagebrush		6	25	4

[1/] Comparisons are weighted averages based on habitat types in general; the same transects were not sampled during each year nor was the sample size equal in every instance. Weighted average = Σ (number plants per species x average utilization of that species)/total number of plants sampled.

All species sampled in the mixed brush habitat type exhibited increases in average leader use between 1978 and 1979. In most instances these increases were slight; however, mountain mahogany leader use increased from 13.0 percent in 1978 to 35.4 percent in 1979. The ANOVA's indicate that there are significant differences between years 1978 - 1979 (main effect) only for mountain mahogany (Table 3-8, Appendix 3-1.6). When the nested effect (transects) is tested, only three species (serviceberry, snowberry, and mountain mahogany) had significant differences in leader use among transects. These changes in use patterns may be associated with abnormal winter conditions, which influenced distributional patterns of the deer herds.

b. Pinyon-Juniper - Utilization of shrubs in the pinyon-juniper type ranged from 0.1 to 66.7 percent (Table 3-6) in 1979. Mountain mahogany, snowberry, and serviceberry exhibited the highest utilization (55.9, 66.7, and 29.0% respectively). Sagebrush, the most abundant species, averaged 11.7 percent utilization as compared to 23.8 percent in 1978. High utilization of mountain mahogany and snowberry indicates that use of these species exceeds

that which is deemed "acceptable" for average winter browse conditions. However, use of the mountain mahogany, a preferred browse species, decreased relative to 1978 use. This decrease might be expected due to harsh winter conditions which caused deer to migrate off tract to elevations lower than those utilized during the 1978 browse season.

The browse condition ratings for mountain mahogany and snowberry were "very poor" for the 1979 sample period. Sagebrush, bitterbrush, and serviceberry had "poor" browse condition ratings, whereas pinyon and juniper had respective classifications of "good" and "excellent". These ratings are similar to those exhibited in 1978.

Average weighted percent utilization for all species in the pinyon-juniper type in 1979 was 15 percent (Table 3-7). This represents a 50 percent reduction from 1978 data and is consistent with the assumption that the harsh winter resulted in reduced or altered browse use patterns in the vicinity of Tract C-a.

The ANOVA indicated significant differences in leader use between 1978 and 1979 (main effect) for sagebrush, bitterbrush, and mountain mahogany (Table 3-8). Sagebrush increased in leader use from 1978 to 1979, whereas bitterbrush and mountain mahogany declined over this time. Although reduction in leader use of pinyon pine was not significant at the .05 level, analyses suggest that differences, such as the decreases noted during 1979, could occur. When the nested effect (transects) was tested, sagebrush and pinyon pine were found to have significant differences in leader use among transects. Differences in leader use among transects for bitterbrush were not significant at the .05 level but were significant at the .10 level (Table 3-8). Differences in leader use patterns may be related to winter weather conditions in the vicinity of Tract C-a.

c. Upland Sagebrush - Sagebrush had an average utilization of 3.9 percent in 1979 and serviceberry exhibited a slightly lower use of 3.3 percent (Table 3-6). These data represent an important decrease from 1978 usage, when respective percentages were 26.3 and 13.5 percent. The 1979 leader use indicates

Table 3-8. Summary of Type I Sum of Squares Analysis of Variance Comparing 1978 and 1979 Browse Leader Use Tract C-a[1/]

Habitat Type	Species	Source of Variation: Year F	Year PR>F [2/]	Among Transects F	Among Transects PR>F [2/]	Interaction F	Interaction PR>F [2/]
MB	Serviceberry	0.24	0.6255	5.17*	0.0001	2.15*	0.0482
	Sagebrush	0.10	0.7560	0.78	0.5679	0.69	0.6340
	Snowberry	1.24	0.2702	2.92*	0.0188	3.55*	0.0185
	Mountain Mahogany	4.38*	0.0472	6.43*	0.0181	2.13	0.1570
	Pinyon Pine	0.99	0.3493	0.33	0.5820	0.33	0.5824
PJ	Sagebrush	9.79*	0.0020	2.72*	0.0073	2.26*	0.0253
	Pinyon Pine	2.96	0.0891	2.90*	0.0181	1.28	0.2806
	Juniper	0.97	0.3279	0.97	0.4141	0.67	0.5743
	Bitterbrush	43.07*	0.0001	2.54	0.0633	1.68	0.1793
	Mountain Mahogany	12.66*	0.0014	1.28	0.2933	0.80	0.4606
	Snowberry[3/]	2.60	0.1583	---	---	---	---
	Serviceberry	0.37	0.6028	1.95	0.2972	1.01	0.4212
SB	Sagebrush	74.25*	0.0001	1.32	0.2529	0.83	0.4796
	Serviceberry	1.38	0.2574	0.66	0.5893	0.26	0.7754
	Snowberry[4/]	---	---	---	---	---	---

* (α= 0.05)

[1/] Complete analyses are presented in Appendix 3-1.5

[2/] PR>F represents the significance probability (α) associated with F

[3/] Species present only on one transect, therefore source of variation occurs only among years

[4/] No leader use during 1979 or 1978

that both sagebrush and serviceberry are well below the allowable use levels for a mild browse winter. As with the other habitat types, reductions in use can be attributed to abnormal winter conditions which resulted in fewer individuals utilizing the area around Tract C-a.

Browse condition ratings for both sagebrush and serviceberry are "fair", as based on the percentage of severely hedged plants. This represents no change from the 1978 data.

Overall utilization for the sagebrush habitat type was 4 percent as compared to 25 percent for 1978 (Table 3-7). Levels of use for 1979 are also lower than those recorded for 1977. Statistical comparison of sagebrush leader use between 1978 and 1979 indicates that the aforementioned reduction is highly significant (PR> F = 0.0001) (Table 3-8, Appendix 3-1.6).

3.2 FAUNA

A. Small Mammal Studies

1. Objectives and Rationale

Intensive reviews of baseline data indicate that reliable small mammal population data such as density, age structure, and species diversity are difficult and costly to obtain. Given reliable data, there is little agreement in the literature about the interpretation of even gross changes in population parameters (Snyder 1978). The RBOSC small mammal program is designed to determine species presence and habitat affinity and to provide indices of relative abundance in important control and treatment habitats. The objectives of the small mammal program are to determine the presence and relative abundance (captures/ 100 trap nights) of small mammals in sagebrush and pinyon-juniper habitats in control and treatment areas, and to compare any changes in time within the habitats within the areas.

2. Methods

a. Trapping - Small mammals are monitored in pinyon-juniper and sagebrush habitat types in a control area just south of the tract boundary and in a treatment area on Airplane Ridge near development activities through 1981 (see Environmental Monitoring Sites Map 2 - Ecological in map pocket for location of control and treatment areas). As development progresses, the treatment area will be moved if necessary.

Three transects are placed in each habitat type for each area. Each transect consists of two lines of ten Sherman live traps; lines and traps are 15 m apart and permanently marked. Bait consists of a mixture of peanut butter and small seeds.

Sampling is conducted in late May - June for three consecutive days. Individuals are identified to species, sexed, aged, marked, and released.

b. Data Analysis - The detection level for this sampling intensity is a function of the number of captures; i.e. as captures increase, confidence about the data will be greater. It is not possible to predict these detection levels a priori since capture numbers are not controllable.

The small mammal data are presented as relative abundance (captures per 100 trap nights) in sagebrush and pinyon-juniper habitats in the control and treatment areas. For each year of the program and for each habitat type, species found in both the control and treatment areas are ranked according to their relative abundances. A Spearman's Rank Correlation Coefficient (SRCC) is then calculated to determine the degree of relationship between the control and treatment data. Coefficients of rank correlation will be compared between years to determine if the relative abundance of small mammal species changes as site development progresses.

The between-year data will be used to test the hypothesis:

H_o: There is no significant difference in the rankings of the relative abundance of small mammal species within each habitat type on control areas or treatment areas, when rankings are compared between years.

The correlations of small mammal data may reflect relationships due to similar habitats supporting similar small mammal populations. Tests of the null hypothesis can indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected for the relative abundance rankings of small mammals within the control and treatment areas, these differences could be due to natural variation, treatment effects, or sampling errors (e.g. differences in phenology between identical calendar dates during the two years). The results of the small mammal sampling program will therefore provide qualitative information about possible effects of site development.

If significant differences between years occur within an area, a detailed analyses of other variables (soil and/or vegetation) sampled will be initiated.

These analyses will indicate if differences reflect small mammal fluctuations or are also evident in these other site variables.

3. Results and Discussions

The numbers of small mammal species captured per 100 trap nights in the control and treatment habitats are presented in Table 3-9. Total small mammal captures by date, trap-number, transect, habitat and area are presented in Appendix 3-2.1. Four species of small mammals were captured in the two habitat types. The deer mouse, Peromyscus maniculatus, was the most frequently captured species in both pinyon-juniper and sagebrush habitats in both the treatment and control areas. The second most frequently captured species was the least chipmunk, Eutamias minimus. These species were also the most frequently trapped during baseline studies (RBOSP 1977). The other species captured were the long tail weasel, Mustela frenata, represented by one capture in the sagebrush habitat in the control area, and the bushytail woodrat, Neotoma cinerea, represented by one capture in the pinyon-juniper habitat in the treatment area. Spearman's Rank Correlation Coefficients could not be calculated because of the small number of species captured (Sokal & Rohlf 1969). A high degree of similarity in small mammal populations may exist in similar habitats as evidenced by the low number of separate species captured and the high number of individuals captured of one species in all habitats.

It is unknown why the population of deer mice was so high--represented by a very high trap success for that species. The high population may have been a result of deep snow which covered the ground for much of the previous winter affording protection to the species from adverse weather and predators, and a wet spring which may have resulted in high vegetation production in some locations. The high trap success for deer mice, both initial captures and recaptures, may have influenced the lack of captures of other small mammal species because a trap with an individual in it is incapable of capturing other individuals of the same or other species.

Results of small mammal trapping will be compared for the same habitats in treatment and control areas between years throughout the remainder of the MDP

Table 3-9. Numbers of Small Mammal Species Live-trapped in two Habitat Types in RBOSC Treatment Area 5 and Control Area 6[1/]

Species	Treatment Area 5		Control Area 6	
	Individuals[2/]	Total Captures[3/]	Individuals[2/]	Total Captures[3/]
Pinyon-Juniper Habitat				
Peromyscus maniculatus	8.33	17.22	31.11	55.55
Eutamias minimus	5.00	7.22	0.55	0.55
Neotoma cinerea	0.55	0.55		
Sagebrush Habitat				
Peromyscus maniculatus	22.22	41.66	34.44	61.66
Eutamias minimus	5.00	5.00	0.55	0.55
Mustela frenata			0.55	0.55

[1/] See RBOSC Environmental Monitoring Sites Map 2 - Ecological in map pocket for location of treatment and control areas

[2/] Number of separate individuals captured per 100 24-hour trapping periods

[3/] Number of total captures per 100 24-hour trapping periods

in an effort to determine if the small mammal population in one area changes in relation to the other area as tract development progresses.

B. Avifauna Studies

1. Objectives and Rationale

There is little, if any, evidence that avifauna sampling programs that are conducted within reasonable constraints of time and money can detect anything except gross changes in bird population parameters or any of many possible natural abiotic or biotic causes (Wiens 1977). The RBOSC avifauna program is designed to determine species composition and relative abundance in important control and treatment habitats (same habitats as monitored for small mammals).

The objectives of the avifauna program are to determine species composition and relative abundance of birds in pinyon-juniper and sagebrush habitats in control and treatment areas, and to compare any changes in time within the habitats within the areas.

2. Methods

a. Observations - Avifauna are monitored in pinyon-juniper and sagebrush habitats in a control area south of the tract boundary and in a treatment area on Airplane Ridge near development activities (see Environmental Monitoring Sites Map 2 - Ecological in map pocket for location of control and treatment areas). These control and treatment areas are in the same locations being used for soil, phytosociological, and small mammal studies. In addition, air studies Site 2 is located near the control area. The multiple sampling program at these two sites will permit future interrelationship interpretations.

Avifauna are monitored by means of a modified Emlen transect method (Emlen 1971 and 1977). Two transects approximately one half-mile long are run in each habitat type in each area during the breeding season. Birds detected within 200 feet of either side of the transect line are recorded. Each habitat is censused on three separate days during early morning hours.

b. Data Analysis - The detection level for this sampling intensity is a function of the number of bird observations; as observations increase, confidence about the data will increase. It is not possible to predict detection levels *a priori* since observation numbers are not controlled by the observer.

The avifauna data are presented as the number of individuals per species and their relative abundance for each habitat in the control and treatment areas. For each year of the program and for each habitat type, species found in the control and treatment areas are ranked according to their relative abundance. A SRCC is then calculated to determine the degree of relationship between the control and treatment for each habitat. Coefficients of rank correlation also will be compared between years to determine if the relative abundance of avifauna species has changed within a habitat as site development progresses.

The between year data will be used to test the hypothesis:

H_o: There is no significant difference in the rankings of the bird species within each habitat type on control or treatment areas, when rankings are compared between years.

The correlations of avifauna data may reflect relationships due to similar habitats supporting similar avifauna populations.

Tests of the null hypothesis can indicate whether or not there are statistically significant differences in the coefficients of rank correlation between years; if the null hypothesis is rejected, it means only that there may have been differences in the relative abundance rankings of avifauna within the control and treatment areas. These differences could be due to natural variation, treatment effects, or sampling errors (e.g. differences in phenology between identical calendar dates during the two years, sample sizes too small). The results of the avifauna sampling program will therefore provide qualitative information about possible effects of site development.

If significant differences between years occur within an area, a detailed analysis of other variables (soil and/or vegetation) sampled there will be

initiated. These analyses will indicate if these differences reflect fluctuations only in avifauna or are also evident in these other site variables.

3. Results and Discussion

Densities and relative abundance of all avifauna species observed during June 1979 sampling in the pinyon-juniper and sagebrush habitats in the control and treatment areas are presented in Tables 3-10 and 3-11 respectively. All avifauna observations by date, transect, habitat and area are presented in Appendix 3-2.2.

More bird species were observed in the pinyon-juniper habitats than in the sagebrush habitats in both the treatment and control areas. This trend was also noted during baseline studies (RBOSP 1977). The most frequently sighted species in the pinyon-juniper habitats were chipping sparrow and black-throated gray warbler in both treatment and control areas. Other frequently observed species in the pinyon-juniper habitat were brown-headed cowbird and mountain bluebird in the treatment area and Brewer's sparrow, green-tailed towhee and common raven in the control area. A total of 12 species was observed in the treatment pinyon-juniper habitat. Twelve species were also observed in the control area pinyon-juniper. Seven bird species were common to treatment and control pinyon-juniper habitats.

In the sagebrush, the most frequently observed species were Brewer's sparrow and green-tailed towhee in both treatment and control areas. The sage thrasher was frequently seen in the sagebrush habitat in the treatment area but was not observed in the control area. A total of four species was observed in the treatment area. Six were observed in the control area sagebrush habitats.

Total number of observations per hectare for all species observed in June in pinyon-juniper and sagebrush habitats during baseline and MDP periods are presented in Table 3-12. These numbers are presented to point out the high variability associated with avian populations in a given habitat from year to year and from area to area. SRCC calculated from the relative abundance date in Table 3-11 indicate no correlation between avifauna species observed between

Table 3-10. Densities[1] of Avifauna Species Observed in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6[2]

Species	Pinyon-Juniper Habitat		Sagebrush Habitat	
	Treatment Area 5	Control Area 6	Treatment Area 5	Control Area 6
Marsh Hawk				.06
Mourning Dove	.11	.07		
Common Nighthawk				.06
Hairy Woodpecker	.06			
Gray Flycatcher		.07		
Magpie		.07		
Common Raven	.22	.35	.07	.06
Pinon Jay		.07		
Mountain Chickadee	.11	.28		
Plain Titmouse		.14		
House Wren	.06			
Sage Thrasher			.43	
Mountain Bluebird	.34	.14		.12
Blue-gray Gnatcatcher	.11			
Solitary Vireo	.11			
Black-throated Gray Warbler	.51	.70		
Brown-headed Cowbird	.40			
Green-tailed Towhee	.22	.35	.43	2.02
Chipping Sparrow	.56	.63		
Brewer's Sparrow		.42	3.55	2.96

[1] Numbers represent number of sightings of each species per hectare

[2] See RBOSC Environmental Monitoring Sites Map 2 - Ecological in Map Pocket for location of treatment and control areas

Table 3-11. Relative Abundances[1/] of Avifauna Species Observed in Two Habitat Types in RBOSC Treatment Area 5 and Control Area 6[2/].

Species	Pinyon-Juniper Habitat		Sagebrush Habitat	
	Treatment Area 5	Control Area 6	Treatment Area 5	Control Area
Marsh Hawk				.01
Mourning Dove	.04	.02		
Common Nighthawk				.01
Hairy Woodpecker	.02			
Gray Flycatcher		.02		
Magpie		.02		
Common Raven	.08	.11	.01	.01
Pinon Jay		.02		
Mountain Chickadee	.04	.09		
Plain Titmouse		.04		
House Wren	.02			
Sage Thrasher			.10	
Mountain Bluebird	.12	.04		.02
Blue-gray Gnatcatcher	.04			
Solitary Vireo	.04			
Black-throated Gray Warbler	.18	.21		
Brown-headed Cowbird	.14			
Green-tailed Towhee	.08	.11	.10	.38
Chipping Sparrow	.20	.19		
Brewer's Sparrow		.13	.79	.56

[1/] Numbers represent number of sightings of each species per hectare divided by the total number of sightings of all species per hectare

[2/] See RBOSC Environmental Monitoring Sites Map 2 - Ecological in Map Pocket for location of treatment and control areas

Table 3-12. Total Avifauna Densities[1/] for all Species Observed in June in Pinyon-Juniper and Sagebrush Habitats during Baseline and MDP periods.

Habitat Type	Baseline 1975	Baseline 1976	MDP - 1979 Treatment	MDP - 1979 Control
Pinyon-Juniper[2/]	2.49	9.34	2.81	3.29
	4.30	8.71		
	4.41	5.94		
	9.96	12.12		
Sagebrush[3/]	1.50	5.47	4.47	5.28
	5.18	4.39		

[1/] Numbers represent total avifauna sightings per hectare

[2/] During baseline avifauna populations were surveyed in several pinyon-juniper associations such as pinyon-juniper/mixed brush. Treatment and control areas for MDP studies were selected for their proximity to the development site and contain a mixture of the pinyon-juniper associations surveyed during baseline.. This table contains avifauna sightings in all associations from baseline data.

[3/] Two sagebrush habitats were surveyed during baseline

treatment and control areas for either habitat. The SRCC between treatment and control areas for pinyon-juniper is .337; the sagebrush SRCC is .420. Because of the inherent variability of avifauna populations, carrying capacities for any habitat are difficult, or impossible, to determine. Tract development impacts, should they occur to avifauna populations, may not be discernable from normal detectable fluctuations. Results of avifauna surveys will be compared for the same habitats in treatment and control areas between years throughout the remainder of the MDP in an effort to determine if the avifauna population in one area changes in relation to the other area as tract development progresses.

C. Mule Deer

1. Objectives and Rationale

Mule deer are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek Basin mule deer herd is one of the largest migratory mule deer herds in North America. Tract C-a is within the Piceance Creek Basin which is within the Colorado Division of Wildlife's (CDOW) Game Management Unit 22.

Moderate to high numbers of mule deer occur on Tract C-a during fall and spring migration periods and during mild winters; at other times mule deer are relatively uncommon on the tract. Consideration of the possible effects of Tract C-a oil shale development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan.

The objectives of RBOSC's mule deer monitoring program are to obtain an index of mule deer density in a 9 x 9 mile (81 sq mi) study area centered on Tract C-a, to compare indices of mule deer density from the study area with those from Game Management Unit 22, and, if possible, to compare differences in mule deer densities within various portions of the study area.

2. Methods

Mule deer densities can be estimated from pellet-group density data since mule deer defecate a reasonably uniform number of times daily (Neff 1968). The

number of pellet-groups per unit area, days of use by deer, and deer per unit area in the Tract C-a study area are determined as described by Overton (1971). The methods followed for collection of these data were described in RBOSC MDP Monitoring Report 1.

3. Results and Discussion

Mule deer pellet groups have been counted every Spring and Fall since 1978 in 20 plots in each of seven 160-acre sample units in each of the nine blocks (nine sq mi per block) comprising the Tract C-a mule deer study area (see Environmental Monitoring Sites Map 2 - Ecological in map pocket). Deer density estimates, based on pellet group counts, for the MDP monitoring period are presented in Table 3-13. Detailed data on each plot for the 1979 sampling period are presented in computer print-out format in Appendix 3-2.3. Statistical analyses are presented as Appendix 3-2.4.

Deer enter the study area in the Fall generally as a result of increasing snow depth or inclement weather which forces them to abandon summer ranges at higher elevation. Because of different individual tolerances to winter conditions, the deer leave the higher elevation and enter the study area over a variable period of time. Depending on weather conditions, migratory deer begin arriving in the study area in late October. The majority of the deer reach the lower elevation by December 1st. Spring migrations from the study area are also dependent on weather conditions, but the movements back to higher elevations generally occur over a shorter period of time once migration is initiated. The majority of the deer leave the study area by April 1st.

Since the exact number of winter deer-use days is unknown for the study area, deer density indices are reported for a series of day totals. Few deer remain in the study area during the Summer period. Pellet counts are conducted in September to obtain a qualitative index of deer numbers during the Summer and to clear the plots for the winter accumulation period. Deer density for the summer is computed using the number of days between the Spring and Fall sampling periods.

Table 3-13. Estimated Number of Mule Deer per Square Mile by Block of the RBOSC Study Area for Two Winter and Two Summer Periods (September 1977 - September 1979)[1/]

Block	Winter Period Days of Deer Use[2/] 120		150		180		210		Average		Summer Period[3/]	
	77-78	78-79	77-78	78-79	77-78	78-79	77-78	78-79	77-78	78-79	78	79
1	83.0	81.9	66.4	65.5	55.3	54.6	47.4	46.8	63.0	62.2	24.9	19.0
2	61.7	95.0	49.3	75.9	41.1	63.3	35.2	54.2	46.8	72.1	28.5	4.7
3	83.0	43.9	66.4	35.1	55.3	29.3	47.4	25.1	63.0	33.4	22.5	7.1
4	56.9	36.8	45.5	29.4	37.9	24.5	32.5	21.1	43.2	28.0	13.0	7.1
5	131.6	95.0	105.3	75.9	87.8	63.3	75.2	54.2	100.0	72.1	17.8	21.4
6	84.2	71.2	67.4	57.0	56.1	47.5	48.1	40.7	64.0	54.1	11.9	7.1
7	51.0	32.0	40.8	24.6	34.0	20.6	29.1	17.6	38.7	23.4	7.1	11.9
8	40.3	33.2	32.3	26.6	26.9	22.1	23.0	19.0	30.6	25.3	7.1	7.1
9	11.9	22.5	9.5	18.0	7.9	15.0	6.8	12.9	9.0	17.1	4.7	20.2
Entire Study Area	67.1	56.8	53.7	45.3	44.7	37.8	38.3	32.4	50.9	43.1	15.3	11.7

[1/] Based on pellet group counts with a defecation rate of 13 pellet groups per deer per day.

[2/] The exact number of days deer were in the study area is unknown; therefore, computations were made using various days of deer use.

[3/] Based on 120 days in the summer accumulation varied.

An Analysis of Variance (ANOVA) was conducted on potential sources of variation within the pellet group data for the two years of sampling. A summary of ANOVA results is presented in Table 3-14. Table 3-15 presents the results of Duncan's Multiple Range Tests on independent sources of variation which exhibited significant differences.

Comparisons of all pellet group numbers counted per block for two years indicate that the tract area (Block 5) has significantly more pellet groups ($\alpha = 0.05$) than six of the nine blocks. The tract area did not have significantly more pellet groups than Blocks 1 and 2 which are located northwest and north of the tract. Statistical comparisons at the 5 percent level of probability show no difference in the average number of pellet groups per sample unit between years. A significant difference ($\alpha = 0.05$) did exist between the number of pellet groups counted in the Spring and the number of groups counted in the Fall for both years.

Several comparisons may be made if the pellet group numbers are extrapolated to represent mule deer densities. The tract and the blocks to the northwest and north sustain more deer use in both summer and winter than other blocks in the 81 sq mi study area. The numbers of deer using the area in 1978 was no different than the number of deer using the area in 1979. More deer were in the study area in the winter than were there in the summer.

The CDOW conducts an annual aerial count of mule deer in the Piceance Basin after the deer hunting season. The number of deer estimated to be in the Basin in 1977 was 34,846 ± 7,980; in 1978 the number was 28,994 ± 4,788. The Piceance Basin count is based on a Basin area of 665 square miles. These numbers give a density estimate of about 52.4 and 43.6 deer per square mile for the winters of 1977-78 and 1978-79, respectively. The RBOSC density estimates for the Tract C-a study area are similar to CDOW estimates; however, the similarity is probably coincidental. At any given time, different parts of the Basin are used as deer winter range depending on the severity of the weather. The elevations and/or aspects used by deer for winter range will vary depending on browse availability, snow depth, and other factors. Deer move within the Basin during a winter to seek out the most favorable conditions. The Tract C-a study area offers only a

Table 3-14. Summary of Analysis of Variance Results on RBOSC Mule Deer Pellet Group Data, Fall 1977 through Summer 1979, Tract C-a and Vicinity[1/]

Source of Variation	Degrees of Freedom	F	PR > F[2/]
Block	8	6.32*	0.0001
Year	1	2.42	0.1211
Season	1	123.99*	0.0001
Block x Year	8	0.82	0.5818
Block x Season	8	3.94*	0.0002
Year x Season	1	0.55	0.4599
Block x Year x Season	8	1.09	0.3730

[1/] Complete analyses are presented in Appendix 3-2.4

[2/] PR > F represents the significance probability (α) associated with F

* ($\alpha = 0.05$)

Table 3-15. Duncan's Multiple Range Tests on Significant Main Effect Sources of Variation for RBOSC Mule Deer Pellet Group Data, Fall 1977 through Summer 1979, Tract C-a and Vicinity[1/]

Source of Variation	Sample Size (N)	Mean	Groupings
Main Effect Block			
5	28	8.00	A
1	28	6.29	A B
2	28	5.71	A B C
6	28	5.29	B C D
3	28	4.71	B C D E
4	28	3.43	C D E F
7	28	3.07	D E F
8	28	2.64	E F
9	28	1.82	F
Main Effect Season			
Winter	126	7.48	A
Summer	126	1.63	B

[1/] Means followed by the same letter are not significantly different ($\alpha = 0.05$)

fraction of the combinations of those factors compared to their availability throughout the Basin, and it is unlikely that the study area would support the same proportion of the deer herd in the Piceance Basin over several winters. What is important is that the estimated deer density in the study area declined along with the estimated deer density in the Piceance Basin.

Continued monitoring of mule deer in the vicinity of Tract C-a and comparisons with CDOW estimates should show what effects, if any, the development of Tract C-a is having on the mule deer herd of the Piceance Basin in the long term.

D. Mule Deer Road Kill Survey

The Piceance Creek Basin is the current center of a great deal of energy development for oil shale and natural gas. This increased activity has resulted in increased traffic flows across mule deer migration routes. The Colorado Division of Wildlife (CDOW) is interested in obtaining data relative to the mortality of mule deer as a result of deer-vehicle collisions.

1. Objectives

The objective of this program is to provide data on mule deer mortality along County Road 24 from Piceance Creek to Tract C-a for compilation and use by the CDOW.

2. Methods

Mule deer mortality data are collected continuously along a 13-mile stretch of County Road 24 from Piceance Creek to Tract C-a during prime migration periods (September - March). Data are recorded on a field log by the RBOSC Wildlife Biologist.

At the initial observance of a new carcass, the location is marked on a map using a number representing the sequential kill count of the month. Duplication of counts is avoided by conspicuously marking the carcass with flagging. Marked carcasses are omitted from subsequent counts. Kill counts, as marked on

the map, plus supplementary data are forwarded to the CDOW (through the Area Oil Shale Supervisor) on a monthly basis.

3. Results and Discussion

Locations of deer killed by collisions with vehicles along County Road 24 from Winter 1978-79 through fall 1979 are shown on Figure 3-2. Deer were very numerous along this road in late Winter and early Spring 1979. One evening in March, approximately 1,300 deer were counted adjacent to the length of County Road 24. Despite the heavy traffic and abundance of deer, only nine deer were killed by collisions with vehicles during the Spring period. During the Fall of 1979 (through November), numbers of deer on Tract C-a and along County Road 24 were low, and only one deer killed by vehicle collision was found during the Fall period. A driver awareness program concerning deer/vehicle collisions has been implemented and is being bolstered with a photographic presentation. This presentation will be incorporated into the tract safety program in an attempt to reduce deer road kills and accidents.

E. Feral Horse Abundance

1. Objectives and Rationale

Feral horses occur on and in the vicinity of Tract C-a. These horses are protected under federal law and are under the jurisdiction of the BLM. Feral horses compete with cattle and, to a lesser extent, with mule deer for available forage. The objective of feral horse monitoring studies is to provide qualitative information concerning the status of feral horses in the RBOSC study area (note: the feral horse study area is the same as the mule deer study area).

2. Methods

The methods followed for collection of data on feral horses were described in RBOSC MDP Monitoring Report 1 and are not repeated herein.

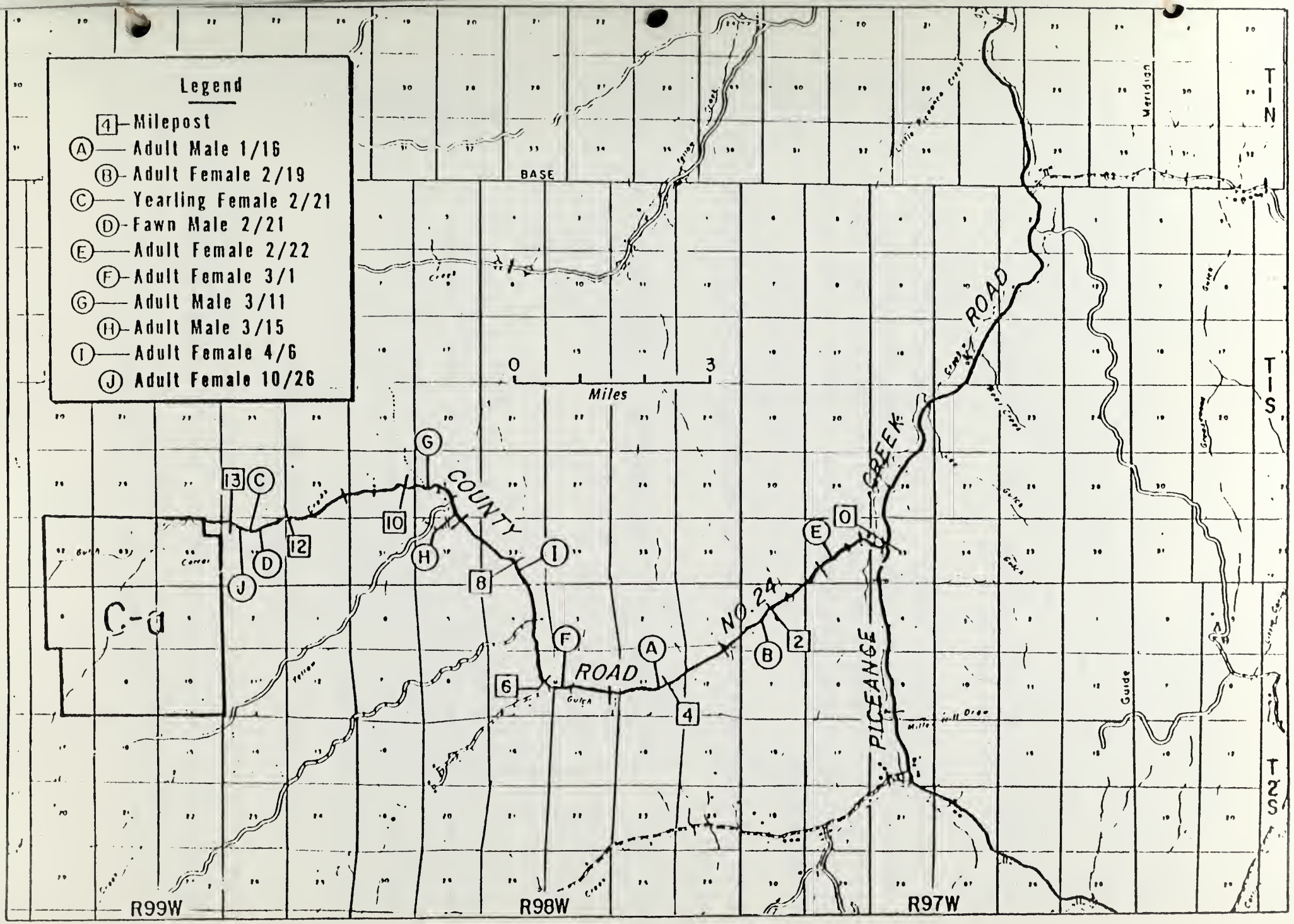

Figure 3-2. Locations of Mule Deer Carcasses found along County Road 24 during the Study Period.

3. Results and Discussion

Feral horses on the Tract C-a study area were counted from a helicopter in January 1979. Twenty one bands of horses totaling 99 individuals were observed in the study area (Figure 3-3). Weather conditions during the count were ideal for horse observation -- a warm, sunny day following several days of snowfall. The January count probably included almost all of the horses in the area since most horses were seen basking in the sun.

During baseline studies, a total of 135 feral horses was estimated to be in two grazing allotments which included part of the RBOSC MDP study area. No feral horses have been removed from the region by the BLM since that time. The density of feral horses observed during 1979 is similar to that estimated during baseline.

Horse age ratios were obtained during September 1979. Age ratios are presented below:

Age Class	No. Observed	% of Tot. Observed
Adult	44	75.9
Yearling	6	10.5
Foal	8	15.8

Because feral horses foal over a long time period in the Summer, some of the horses may have been counted in the incorrect Age class. An annual 15 to 20 percent increase in the feral horse population is expected by the BLM. The low foal proportion may have been the result of the severe winter of 1978-79 which could have caused abortions in some mares.

E. Threatened, Endangered, and Protected Species

Baseline and interim monitoring studies indicate that Tract C-a does not provide critical habitat for any state or federally endangered species. Greater sandhill cranes were observed during the baseline studies on 84 Mesa, at the Stake Springs impoundment, and east of 84 Ranch. An immature whooping

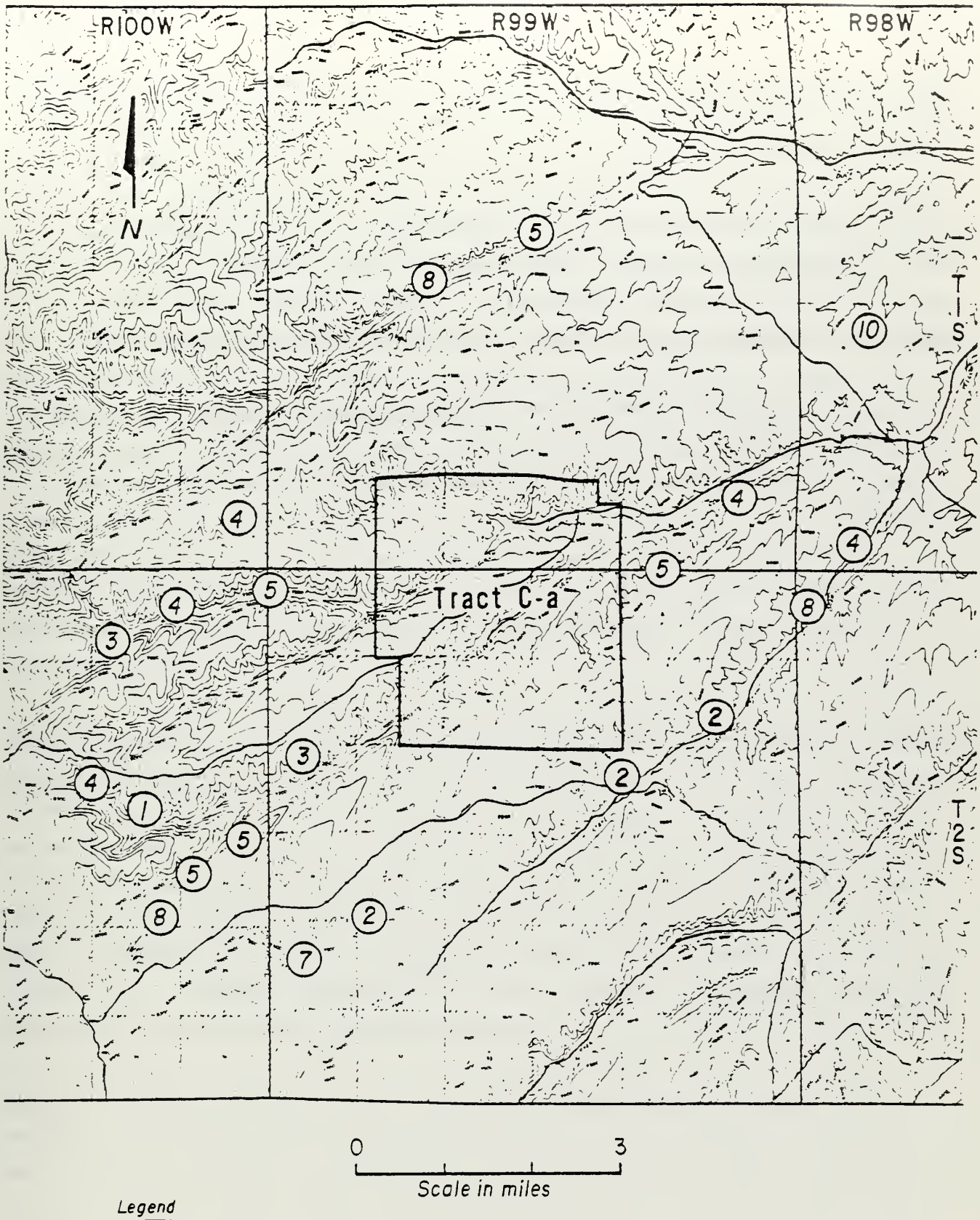

Figure 3-3. Feral Horse Observations, Tract C-a

crane was sighted east of 84 Ranch during baseline studies. Neither of these species was observed during the reporting period nor have they been observed in recent studies.

Several raptor species (golden eagle, Cooper's hawk and sharp-shinned hawk), that are protected in Colorado, were seen during the reporting period. These species are not threatened or endangered. However, their status is of concern because they are becoming more rare in certain areas of the United States.

A pair of golden eagles, protected in Colorado, nested at Milepost 5 along County Road 24 during the reporting period. One eagle fledged from that nest on July 4, 1979, in spite of heavy road traffic and the paving of that road during June.

3.3 SUMMARY

The components of the Terrestrial Monitoring Program examined during the December 1978 through November 1979 reporting period include vegetation mapping and stress, phytosociological, range production and utilization, browse utilization and condition, small mammal, avifauna, mule deer, and feral horse studies.

Color infrared photographs from 1974 were studied and "moist pockets" identified. Comparisons with 1979 photographs indicated that those areas identified from 1974 photography also were evident during 1979. Preliminary determinations suggest increases in moisture balance in some areas. These increases may be attributable to natural variations between years in many instances. However, increases noted in several portions of Corral Gulch, and one location in Box Elder Gulch, seem to be related to reinjection and/or dewatering discharge. Although vegetation changes have not been observed within each of these areas, expected changes would be reductions in bottomland sagebrush and increases in grass communities.

Phytosociological studies were conducted on ten transects (5 control, 5 treatment) within the pinyon-juniper habitat type on and adjacent to Tract C-a. Coverage of trees and shrubs was similar between the study areas, but density of woody species was greater within the treatment area. Herbaceous vegetation averaged 13.7 percent coverage in the control area and 14.8 within the treatment area. There was no significant difference ($\alpha = 0.05$) in herbaceous coverage between areas. Graminoid species were the dominant contributors to herbaceous coverage in both areas. Bluegrass (Poa spp.) and Indian Ricegrass (Oryzopsis hymenoides) were the most prevalent grass species observed.

Range productivity and utilization studies indicated that production varied from 44 kg/ha in the pinyon-juniper to 209 kg/ha in the mixed brush habitat type. Production within the mixed brush and pinyon-juniper types was similar to that recorded in 1978, but increased significantly ($\alpha = 0.05$) within the sagebrush type. Relative to 1978, percent utilization increased in the mixed brush type, and decreased within both the pinyon-juniper and upland sagebrush types. Graminoid species were used more heavily than were forbs in all three

vegetation types. Data indicate that variability in both production and utilization is inherent within the ecosystems being studied. Therefore, definitive trends for production and/or utilization cannot be ascertained at this time.

Browse condition and utilization data show that average utilization decreased between 1978 and 1979 within the pinyon-juniper and upland sagebrush vegetation types, whereas utilization for the mixed brush type remained about the same. Mountain mahogany (Cercocarpus montanus) use increased significantly ($\alpha = 0.05$) within the mixed brush type in 1979, but decreased significantly ($\alpha = 0.05$) within the pinyon-juniper type. Sagebrush (Artemisia tridentata) utilization was significantly greater within the pinyon-juniper type in 1979, and significantly lower ($\alpha = 0.05$) in the upland sagebrush type. Browse use ratings were similar to those reported for 1978, and indicated that, for the most part, utilization values were "acceptable" for average winter range. Browse condition also was similar to that for 1978 and ranged from "poor" to "good" depending on the species and/or vegetation type being considered. RBOSC browse data are based on consideration of the same individual plants on a yearly basis and, consequently, do not reflect changes in age structure of browse species which may be taking place. Furthermore, one should take caution in making basin-wide generalizations based on these data.

Four small mammal species were captured during the 1979 sampling period. The deer mouse was the most frequently trapped species in both pinyon-juniper and sagebrush habitats in both the treatment and control areas. The least chipmunk was the second most frequently caught. These species were also the most frequently caught during baseline studies. The ratio of deer mice caught per 100 trap nights during the sampling period for all areas was higher than that ratio during baseline. Small mammal populations normally fluctuate widely, and the high deer mouse population may have been a result of deep snow which covered the ground for much of the previous winter. The deep winter snows may have provided protection from adverse weather and predators and ample moisture for a wet spring which then resulted in greater vegetation production in some locations. The high trap success for deer mice may have reduced the number of captures of other small mammal species because a trap with an individual in it is incapable of capturing other individuals of the same or other species.

More species of birds were observed in the pinyon-juniper habitat than in the sagebrush habitat in both the treatment and control areas. This distribution was also noted during baseline studies. A total of 12 bird species was observed in the treatment area, and 12 species also were observed in the control area of the pinyon-juniper habitat type. A total of four bird species was observed in the treatment sagebrush habitat, and six were observed in the control sagebrush type.

The most frequently sighted species in the pinyon-juniper habitats were the chipping sparrow and the black-throated gray warbler in both treatment and control areas. Other frequently observed species in the pinyon-juniper habitat were the brown-headed cowbird and the mountain bluebird (treatment area) and Brewer's sparrow, the green-tailed towhee, and the common raven (control area). In the sagebrush habitat, the most frequently observed species were Brewer's sparrow and the green-tailed towhee in both treatment and control areas. The sage thrasher was frequently seen in the sagebrush habitat in the treatment area, but was not observed in the control area. There appeared to be little correlation between the bird populations in the same habitat type in the treatment versus the control areas. Similar variability between bird populations in the same habitat types were noted during baseline studies.

Based on pellet group counts, mule deer use in 1979 was not significantly different ($\alpha = 0.01$) in the area north and northwest of the tract than in other parts of the study area. If the numbers of pellet groups are extrapolated to represent numbers of deer, about 50.9 and 43.2 deer per square mile were on the RBOSC study area during the winters of 1977-78 and 1978-79, respectively. These numbers are similar to estimates by the Colorado Division of Wildlife (52.4 and 43.6 deer per square mile) for the same years.

Ten deer were killed by collisions with vehicles along Rio Blanco County Road 24 during the spring and fall (through November) migration period in 1979. Deer were very numerous along this road during the spring period, accounting for nine of the ten deer killed. However, the number of road kills is low considering the heavy traffic and poor road conditions during that time.

A total of 99 feral horses in 21 bands was counted in the 81 sq mi study area in January 1979. During the foal count in September, it was estimated that about 16 percent of the feral horse population in the area was composed of young-of-the-year.

No threatened or endangered species were observed in the vicinity of Tract C-a during the reporting period. A protected species, the golden eagle, nested and successfully fledged one chick near Rio Blanco County Road 24 during the summer.

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SECTION 4
AQUATIC STUDIES

The MDP Aquatic Monitoring Program is designed to provide information on aquatic ecosystems in the vicinity of Tract C-a appropriate to identifying and measuring the potential effects of modular development on local aquatic biota. The program design was based on a complete evaluation of data obtained during the RBOSC baseline program and upon projected impacts of project activities. Criteria for selecting aquatic parameters to be measured included ecological importance, sensitivity to environmental change, and ease of sampling. Parameters sampled can be categorized as follows:

- Abiotic components
  1. physical measurements
  2. water quality measurements
- Biotic components
  1. periphyton
  2. benthos

A detailed list of parameters measured at each sampling location and sampling frequency is provided in Table 4-1. Six sampling sites are used in the MDP monitoring program (Figure 4-1). A description of each site follows:

- Station 13 (spring-brook habitat) at the USGS gauging station in Corral Gulch (east)
- Station 14 (pond habitat) in Corral Gulch (east)
- Station 20 (spring-brook habitat) at the USGS gauging station on Yellow Creek
- Station 21 (spring-brook habitat) on Yellow Creek below the USGS gauging station
- Station 27 and 29 (White River back channel habitats) above and below the confluence of Yellow Creek with the White River

Table 4-1. Aquatic Studies Monitoring Schedule

Parameter	Location	Frequency
Abiotic Component		
Physical Measurements		
Stream Velocity		
Turbidity		
Dissolved Oxygen	Stations 13, 14, 20, 21, 27, 29 (See Figure 4-1)	6 times/year (Apr., May, June, July, Aug., Oct.)
pH		
Specific Conductance		
Depth		
Width		
Stream Substrate		
Water Quality Measurements (White River)		
Boron		
Calcium		
Chloride		
Fluoride		
Magnesium	Stations 27, 29 (See Figure 4-1)	6 times/year (Apr., May, June, July, Aug., Oct.)
Nitrate		
Orthophosphate		
Total Phosphate		
Potassium		
Silica		
Sulfate		
Sodium		
Alkalinity		
Total Dissolved Solids		

Table 4-1. (Continued)

Parameter	Location	Frequency
Biotic Component		
Periphyton		
species composition relative abundance biomass diversity	Stations 13, 14, 20, 21, 27, 29 (See Figure 4-1)	6 times/year (Apr., May, June, July, Aug., Oct.)
Benthos		
species composition relative abundance diversity	Stations 13, 14, 20, 21, 27, 29 (See Figure 4-1)	6 times/year (Apr., May, June, July, Aug., Oct.)

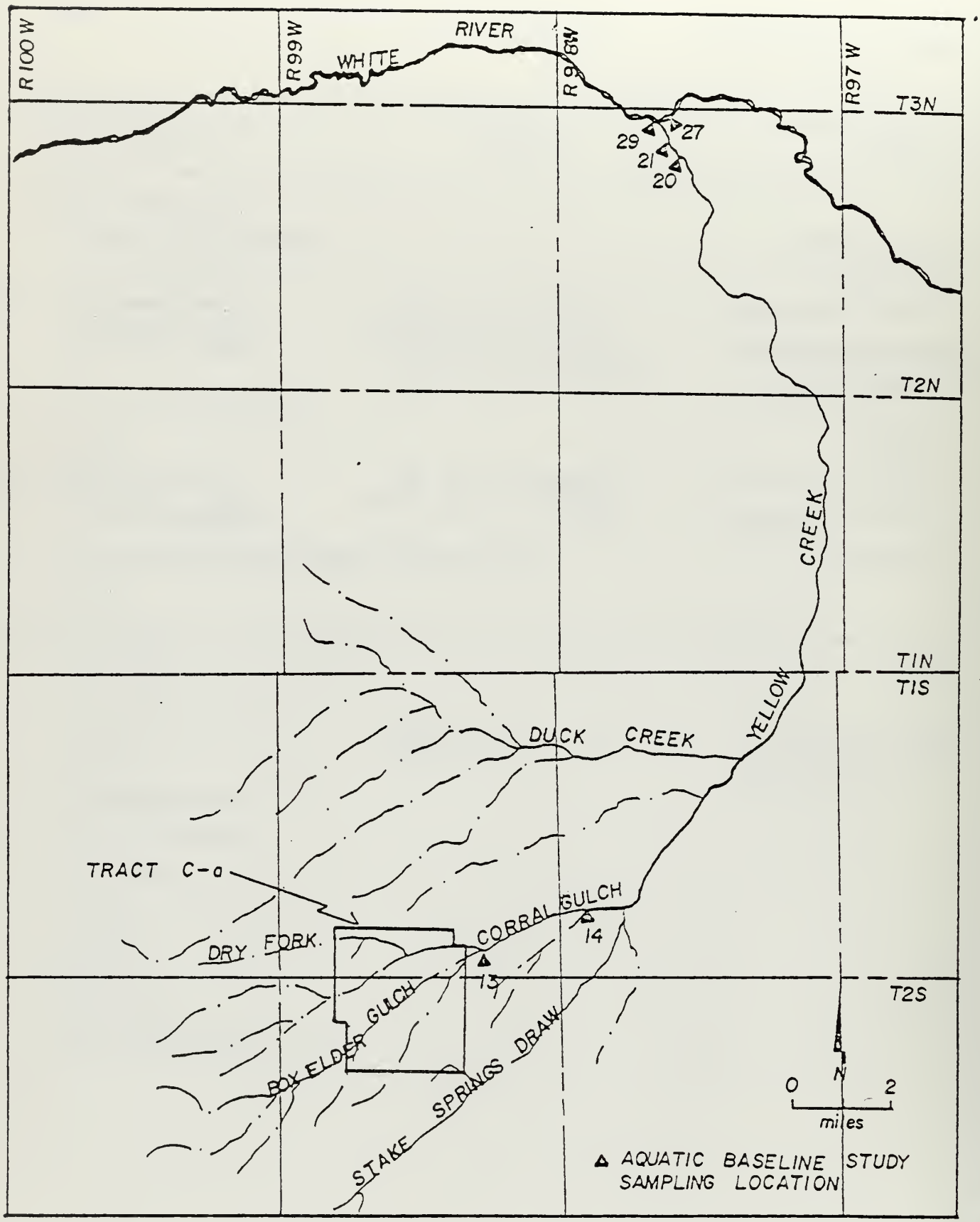

Figure 4-1. Locations of Aquatic Sampling Sites, RBOSC, Tract C-a.

Sampling was initiated in October 1977. This report provides results for the 1979 MDP Aquatic Sampling Program. It includes comparison with MDP sampling results and data collected during the baseline program (1974-1976).

4.1 ABIOTIC COMPONENTS

A. Physical Measurements

1. Objectives

Changes in the physical characteristics of an aquatic system can have a direct and immediate effect on water quality and aquatic biota. Measurements of selected physical characteristics at MDP aquatic monitoring stations can provide important information relative to evaluating water quality and biological data; moreover, physical data may be useful in determining if changes from aquatic baseline conditions are the result of natural variability or project activities.

The physical parameters selected for monitoring are those which may be indicative of effects related to project activities (e.g., increased siltation and turbidity and decreased flows) and which have shown to be of particular significance to the important aquatic organisms observed during baseline studies. Chemical parameters, such as dissolved oxygen, which are recorded in conjunction with the physical measurement program, are presented and discussed in this section as well.

2. Methods

Methods used to collect stream data were described in RBOSC MDP Monitoring Report 1.

3. Results and Discussion

A comparison of physical measurement data collected during 1979 MDP studies with results obtained during previous years is provided in Tables 4-2 - 4-7. The data in Tables 4-2 - 4-7 indicate a good deal of seasonal and year-to-year variability in physical parameters. With a few exceptions, no consistent trends or permanent change is apparent in any given parameter at any station. A large increase in the volume of flow has occurred at Station 13 and 14 (Figure 4-1) because of the operational discharge of water into Corral Gulch. The higher flow has resulted

Table 4-2. Physical and Chemical Characteristics at Station 13 for RBOSC MDP Studies (1977-19/9) and RBOSC Baseline Studies (1974-1976)

	Station 13									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
Baseline										
10-11/74	10	1,200	8.9	410	7.8	2	Sa,Gr	3.0	1,1,1.5	0.5
4/75	9	1,730	5.2	716	8.3	>1,000	Gr,Si	3.0	3	1.0
5-6/75	20	1,500	5.6	646	8.3	450	Gr,Sa,Si	4.2	4	1.7
7-8/75	18	1,200	6.2	396	7.5	6	Gr,Sa	2.8	3	2.0
8-9/75	11	1,300	7.6	419	7.6	1	Gr,Sa	2.5	4	1.1
10/75	13	1,200	8.4	421	7.8	1	Gr,Sa	2.0	3	1.9
4/76	13	1,150	7.8	435	7.5	>1	Gr,Sa	4.0	4	1.4
5-6/76	18	1,100	6.1	379	7.8	163	Gr,Sa	2.5	5	2.1
7-8/76	15	1,200	7.1	381	8.0	4	Gr,Sa	3.0	3	2.1
8-9/76	15	1,100	7.0	397	7.9	12	Gr,Sa	3.0	2	1.4
MDP										
10/77	19	1,200	8.0	401	7.8	-	Gr	3.5	2	0.7
4/78	17	1,500	5.1	584	8.3	60.0	Gr	3.5	6	2.0
6/78	13	1,500	6.4	410	7.8	520.0	Gr,Sa	3.0	6	2.9
7/78	15	1,400	6.6	302	8.1	-	Gr,Sa	5.0	6	2.3
8/78	12	1,600	7.4	482	8.0	8.8	Gr	4.0	4	1.7
10/78	11	1,800	7.9	496	7.8	1.5	Gr	4.5	7	2.0

Table 4-2 (Continued)

Station 13										
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
MDP Cont.										
4/79	15	1,050	6.3	450	7.8	155	Gr	4.8	9	2.5
5/79	13	955	6.9	423	7.9	420	Gr	6.3	7	3.2
6/79	15	1,375	5.3	454	10.2	44	Gr	7.3	4	1.9
7/79	15	1,225	12.3	447	8.3	-	Gr,Sa	7.5	4	1.2
8/79	17	1,413	4.7	482	7.9	32	Gr,Sa	6.0	4	2.1
10/79	17	1,325	7.2	413	8.1	12	Gr,Si	4.8	4	1.9

[1] Substrate abbreviations: Gr-Gravel; Sa-Sand; De-Detritus; Co-Cobble; Si-Silt

Table 4-3. Physical and Chemical Characteristics at Station 14 for RBOSC MDP Studies (1977-1979) and RBOSC Baseline Studies (1974-1976)

	Station 14									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
Baseline										
10-11/74	8	1,800	13.4	454	8.2	1	Cl	1.0	6	1.3
4/75	5	1,800	11.1	492	8.4	9	Si	0.3	2	0.5
5-6/75	18	1,550	12.6	485	8.2	2	Sa,Cl	2.5	3-6	0.0
7-8/75	19	2,000	12.9	532	7.9	7	Sa,Si	3.6	3-6	0.0
8-9/75	12	1,850	7.4	564	7.9	2	Si	2.4	4	1.0
10/75	14	1,800	14.4	520	8.3	4	Si	3.0	6	0.4
4/76	9	1,750	9.7	546	7.9	3	Sa	1.5	4	1.2
5-6/76	24	1,750	12.3	510	8.2	2	Gr,Sa	1.5	6	1.1
7-8/76	23	1,700	8.5	528	8.0	14	Sa	0.3	3	1.5
8-9/76	17	1,200	8.5	542	8.1	>1	Sa	0.3	2	1.5
MDP										
10/77	8	1,700	9.8	521	7.7	-	Sa,De	0.3	2	0.7
4/78	16	1,400	10.1	424	8.4	25.0	Sa,Si,De	0.5	6	1.0
6/78	16	1,600	8.6	-	8.4	-	Sa	3.0	9	1.9
7/78	14	1,700	9.4	530	8.1	-	Gr,Si	2.0	6	1.3
8/78	11	1,800	10.1	495	8.2	1.3	Sa,Si	3.0	12	0.6
10/78	6	1,850	9.0	510	7.6	1.0	Si,Gr	4.5	9	1.3

Table 4-3 (Continued)

Station 14

DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
				PARAMETERS						
MDP Cont.										
4/79	12	2,000	8.5	600	7.0	1.0	Sa,Si	8.5	8	1.0
5/79	9	1,500	7.6	529	7.4	2.8	Sa	9.0	5	0.5
6/79	11	2,150	8.7	749	8.4	0.8	Gr	7.5	15	0.4
7/79	9	2,200	7.7	515	7.2	-	Si,Gr	5.7	6	0.9
8/79	10	2,463	6.7	527	7.5	13.5	Si,Sa,Gr	5.2	9	0.8
10/79	11	2,175	7.5	520	7.6	3.0	Si,Gr	6.3	11	0.3

[1] Substrate abbreviations: Gr=Gravel; Sa=Sand; De=Detritus; Co=Cobble; Si=Silt

Table 4-4. Physical and Chemical Characteristics at Station 20 for RBOSC MDP Studies (1977-1979) and RBOSC Baseline Studies (1974-1976)

	Station 20									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
Baseline										
10-11/74	7	3,000	8.7	1,149	8.5	12	Gr	2.3	4.5	1.7
4/75	14	3,700	9.4	1,291	8.6	81	Gr,Si,Sa	1.0	3.5	1.3
5-6/75	23	3,600	8.2	1,393	8.3	7	Gr,Sa	0.8	4	1.4
7-8/75	19	3,800	8.7	1,375	8.8	7	Sa,Si	3-6	36	1.4
8-9/75	25	3,300	7.2	1,650	8.7	28	Si,Gr,Sa	5.4	3	0.7
10/75	11	3,850	10.6	1,485	8.7	13	Gr,Sa	3.3	3	1.3
4/76	19	4,000	9.4	1,632	8.7	110	Gr	5.0	4	1.1
5-6/76	22	4,200	6.3	1,740	8.0	12	Gr,Sa	3.0	5	1.8
7-8/76	31	4,500	8.6	1,664	8.0	3	Gr,Sa	0.8	3	1.1
8-9/76	11	4,000	7.4	1,456	8.7	58	Gr	6.0	3	1.2
MDP										
10/77	11	4,100	7.1	1,658	8.6	-	Gr,Sa	1.8	0.7	1.9
4/78	16	4,200	8.2	1,444	8.1	75	Co,Gr	3.0	4	1.5
6/78	25	4,800	6.5	-	8.8	-	Gr,Sa	2.0	5	1.3
7/78	23	5,000	7.4	2,700	8.9	-	Gr,Sa	1.0	5	1.4
8/78	24	4,600	7.4	2.286	9.2	5	Gr,Si	2.0	3	0.7
10/78	11	5,000	7.4	1,732	8.6	2	Gr,Si	5.5	3.5	0.9

Table 4-4 (Continued)

Station 20										
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
MDP Cont.										
4/79	22	2,500	8.7	1,544	8.3	120.0	Gr,Sa	6.7	5	1.3
5/79	24	4,030	7.1	1,620	8.1	66.0	Gr	5.3	6	2.1
6/79	21	4,100	6.7	1,616	9.7	4.4	Gr	6.2	6	1.4
7/79	18	3,650	5.8	1,476	8.7	2.0	Gr	6.6	4	1.5
8/79	21	3,625	7.4	1,370	8.0	16.0	Gr,Si	10.7	3	0.6
10/79	8	3,050	9.0	1,140	8.2	15.0	Gr,Si	9.2	4	1.2

[1] Substrate abbreviations: Gr=Gravel; Sa=Sand; De=Detritus; Co=Cobble; Si=Silt

Table 4-5. Physical and Chemical Characteristics at Station 21 for RBOSC MDP Studies (1977-1979) and RBOSC Baseline Studies (1974-1976)

	Station 21									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity (μmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
Baseline										
10-11/74	8	3,000	9.9	1,244	8.6	2	Sa,Gr	3.0	1	1.0
4/75	14	3,700	8.9	1,306	8.6	68	Gr,Si	5.4	4	1.5
5-6/75	18	3,400	9.2	1,449	8.3	3	Gr,Sa	5.0	4	2.3
7-8/75	19	3,900	8.1	1,451	8.7	8	Gr,Sa	4.5	3	0.8
8-9/75	24	3,900	8.8	1,651	8.7	25	Gr,Sa	2.7	4	1.2
10/75	8	3,880	10.7	1,567	8.7	20	Gr,Sa	3.3	3	2.0
4/76	18	3,900	10.2	1,658	8.7	100	Gr	6.0	4	0.9
5-6/76	17	3,900	7.4	1,660	8.5	14	Gr,Sa	12.0	6	0.7
7-8/76	28	4,000	10.2	1,558	8.0	14	Gr,Si	6.0	4	0.6
8-9/76	11	4,000	7.6	1,600	8.7	176	Gr,Sa,Si	1.0	5	0.7
MDP										
10/77	12	4,100	7.9	1,650	8.8	-	Gr	3.0	3	1.0
4/78	13	4,200	6.9	1,532	8.7	75.0	Gr,Sa	4.0	4	1.0
6/78	20	4,900	6.7	-	8.9	-	Gr,Sa	3.5	6	1.7
7/78	23	4,800	7.5	1,404	9.0	-	Gr,Sa	4.0	4	0.9
8/78	22	3,800	5.9	2,190	9.0	10.0	Sa,Si	4.0	6	1.0
10/78	11	5,000	7.2	2,058	8.6	1.5	Gr	4.5	2	1.2

Table 4-5 (Continued)

DATE	Water Temp. (°C)	Conductivity (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth (in)	Velocity (fps)
Station 21 PARAMETERS										
MDP Cont.										
4/79	21	3,220	8.6	1,554	8.4	145.0	Gr,Sa	9.3	3	1.7
5/79	28	4,350	5.2	1,590	8.3	75.0	Gr	6.3	4	1.4
6/79	21	4,300	6.8	1,662	9.5	6.4	Gr	7.2	4	1.7
7/79	22	3,650	6.6	1,490	8.6	1.0	Gr	7.5	3	1.4
8/79	24	3,587	7.4	1,298	8.2	14.5	Gr,Si	8.3	4	0.8
10/79	13	2,988	8.2	1,060	7.8	17.0	Gr,Si	5.1	4	1.7

[1] Substrate abbreviations: Gr=Gravel; Sa=Sand; De=Detritus; Co=Cobble; Si=Silt

Table 4-6. Physical and Chemical Characteristics at Station 27 for RBOSC MDP Studies (1977-1979) and RBOSC Baseline Studies (1974-1976)

	Station 27									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity[2] (μmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth[2] (in)	Velocity[2] (fps)
Baseline										
10-11/74	11	600,600,700	12.1	199	8.6	7	Co	45	2,19,14	0.4,0.4,0.6
4/75	15	850	9.8	207	8.5	44	Gr,Si	46.5	2,23,4	0.4, - ,1.2
5-6/75	12	350	8.9	109	8.0	64	Co	-	36	1.6, - ,1.2
7-8/75	18	625,625,625	8.5	473	8.2	28	Sa,Si	45	8,28,18	0.4, - ,1.2
8-9/75	18	825,800,800	10.9	206	8.6	10	Co,Sa	45	20,12,7	0.1, - ,0.9
10/75	9	775,700,700	11.1	186	8.3	9	Co,Gr	50	10,22,22	0.2,0.6,1.0
4/76	17	650,640,650	10.6	188	8.4	32	Co	51	4,22,8	1,2,1.0,0.7
5-6/76	18	550,550,550	8.0	157	8.0	13	Co	56	8,26,6	0.3,1.4,0.7
7-8/76	20	950,925,925	7.3	256	8.0	250	Co,Si	46	22,22,18	0.7,0.8,0.4
8-9/76	20	900,900,900	9.7	217	8.4	4	Co,Gr	46.5	16,16,1	0.9, - ,-
MDP										
10/77	9	900,900,900	9.6	214	8.3	59.0	Co	39	1,10	0.8,1.1,-
4/78	9	700,700,700	9.6	184	8.2	89.0	Co,Si	51	8,10,4	1.2,1.9,1.4
6/78	12	550	8.2	136	8.2	54.0	-	-	-	-
7/78	21	670,670,670	7.9	180	8.7	6.0	Co,Si	60	8,10,8	2.1,2.5,1.7
8/78	19	700,700,700	10.2	180	8.7	1.0	Co	40	6,10,6	1.9,2.1,2.1
10/78	7	800	10.3	178	8.0	0.9	Co,Si	52	6,14,4	-, 1.4, -

Table 4-6 (Continued)

Station 27										
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity[2] (µmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth[2] (in)	Velocity[2] (fps)
MDP Cont.										
4/79	12	600,600,600	9.3	182	7.5	97.5	Gr	54.3	14,15,18	1.9,2.0,1.0
5/79	12	450	8.1	130	8.0	150.0	Gr	-	-	-
6/79	10	350	8.7	145	8.2	50.0	-	-	-	-
7/79	20	450	7.7	162	8.4	18.0	Gr	54.2	26,11,9	2.1,2.1,1.1
8/79	18	813	7.1	227	8.2	9.0	Gr,Sa	48.5	6,12,14	1.3,2.3,2.3
10/79	9	725	8.2	180	7.9	14.0	Sa,Si,Gr	51.0	10,17,28	0.5,0.4,1.6

[1] Substrate abbreviations: Gr=Gravel; Sa=Sand; De=Detritus; Co=Cobble; Si=Silt

[2] When water conditons permitted, three measurements were taken at the left, center, and right portions of the river (facing upstream)

Table 4-7. Physical and Chemical Characteristics at Station 29 for RBOSC MDP Studies (1977-1979) and RBOSC Baseline Studies (1974-1976)

	Station 29									
	PARAMETERS									
DATE	Water Temp. (°C)	Conductivity[2] (μmhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth[2] (in)	Velocity[2] (fps)
Baseline										
10-11/74	11	855,750,690	10.8	224	8.7	8	Co,St	22.6	1,12,2	3.4, -,2.3
4/75	13	850	10.1	207	8.4	53	Gr,D	20.8	1,11,1	1.9, -,3.6
5-6/75	12	400	8.9	123	8.0	48	Co	-	20,-,20	5.8, -,3.1
7-8/75	18	750,675,625	8.2	453	8.2	20	Co,Gr	35	7,16,6	2.1, -,3.1
8-9/75	18	825,900,875	10.2	230	8.6	15	Co,Sa	45	7,12,7	2.3, -,2.5
10/75	9	875,760,710	10.9	192	8.3	9	Co,Gr	26	9,13,8	4.5,4.5,1.8
4/76	11	730,800,1150	10.5	186	8.4	43	Gr,Sa	25	4,12,2	2.8,3.9,1.9
5-6/76	19	675,525,500	8.1	175	8.1	14	Co	33	3,16,14	2.1,3.1,3.7
7-8/76	20	1050,1000,900	7.4	278	8.0	365	Co	24	8,11,5	1.2,3.2,2.5
8-9/76	20	1000,950,900	9.6	240	8.4	20	Co	29.4	8,8,3	3.3, - , -
MDP										
10/77	9	900,1050,1200	9.7	269	8.1	67.0	Co	26	2,-,8	1.2, - ,2.3
4/78	9	700,700,700	9.6	184	8.2	95.0	Co,Si	51	8,10,4	1.2,1.9,1.4
6/78	12	- ,550, -	8.2	136	8.2	7.0	-	-	-	-
7/78	21	680,680,750	7.5	183	8.7	8.0	Co,Gr	22	8,12,6	2.0,3.4,2.3
8/78	19	700,700,750	10.2	178	8.7	1.2	Co	23	6,16,4	1.4,2.4,1.3
10/78	7	- ,780, -	10.2	170	8.0	1.0	Co	35	7,15,9	0.8,0.6,0.7

Table 4-7 (Continued)

Station 29

DATE	Water Temp. (°C)	Conductivity[2] (umhos/cm)	Diss. Oxygen (mg/l)	Total Alkalinity (mg/l)	pH	Turbidity (JTU)	Substrate[1]	Width (ft)	Depth[2] (in)	Velocity[2] (fps)
				PARAMETERS						
MDP Cont.										
4/79	12	600,600,1000	9.5	179	7.5	103.0	Gr	41.5	10,11,14	2.3,3.6,2.1
5/79	12	450	8.2	219	8.0	140.0	Gr	-	-	-
6/79	11	675	8.5	232	8.4	46.0	-	-	-	-
7/79	19	500	7.6	164	8.7	19.0	Gr	36.7	10,17,19	2.9,2.8,2.6
8/79	18	788	7.6	229	8.1	9.0	Sa,Gr	28.2	7.5,14,16	2.1,2.3,2.8
10/79	9	825	9.0	178	7.9	20.5	Sa,Gr	26.5	7,10,12	2.2,2.0,2.9

[1] Substrate abbreviations: Gr=Gravel; Sa=Sand; De=Detritus; Co=Cobble; Si=Silt

[2] When water conditions permitted, three measurements were taken at the left, center, and right portions of the river (facing upstream)

in an increase in the width, depth and velocity at these two stations. Conductivity and turbidity both seem to be increasing at Station 13 and could be related to water discharge effects. No large difference in the parameters recorded for stations at Yellow Creek (20 and 21) and the White River (27 and 29) are noted for the MDP and Aquatic Baseline Program.

B. Water Quality Measurements

1. Objectives

Water quality has important ramifications to both the many potential uses of the White River and the distribution and abundance of White River biota. Any change in water quality resulting from project activities, must be adequately and quickly detected by the MDP Aquatic Monitoring Program. Measurement of certain key chemical parameters at stations along the White River above and below the influx of water from the project site will provide a good index to water quality. These parameters were selected on the basis of results obtained during baseline studies and represent the best indicators of natural variability in White River water quality. Water quality data for other surface waters of the site are collected during hydrology studies (Section 5).

2. Methods

Methods used to collect and analyze water quality samples were described in RBOSC MDP Monitoring Report 1.

3. Results and Discussion

Water quality data for Station 27 are presented for 1977-1978 and 1979 MDP studies in Tables 4-8 and 4-9, respectively. Station 29 chemical data are presented for the same periods in Tables 4-10 and 4-11. A summary of water quality data for Stations 27 and 29 collected during baseline studies (1974-1976) is presented in Tables 4-12 and 4-13, respectively.

The data in Tables 4-8 - 4-13 indicate no large change in White River water

Table 4-8. Water Quality Data for the White River, RBOSC MDP Aquatic Monitoring Studies, October 1977 - October 1978

Parameter[1/]	Station 27											
	10/77		4/78		6/78		7/78		8/78		10/78	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	--	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	--
Calcium (Ca)	84	83	72	70	37	37	65	67	69	69	67	67
Chloride (Cl)	43	43	29	29	16	12	25	24	34	33	32	32
Fluoride (F)	0.17	0.17	0.27	0.26	0.18	0.12	0.23	0.23	0.28	0.29	0.26	0.22
Magnesium (Mg)	28	31	24	24	13	12	20	19	23	26	20	20
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	0.01	<0.01	0.01	0.01	0.06	0.22	0.03	0.03	<0.01	<0.01	<0.01	0.01
Phosphorus, Total (P)	0.02	0.01	0.02	0.02	0.12	0.32	0.04	0.03	<0.01	0.01	<0.01	0.01
Potassium (K)	2.8	2.7	2.1	2.1	2.2	1.9	2.6	2.5	2.4	2.5	2.1	2.2
Silica (Si)	8.3	8.3	6.2	6.4	5.9	5.7	8.4	8.3	6.9	6.7	6.9	6.9
Sodium (Na)	67	66	47	47	42	31	40	39	46	47	47	47
Solids, Total	512	529	441	446	302	279	401	354	447	450	419	413
Sulfate (S)	60	60	48	50	20	17	38	39	46	47	44	45

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-9. Water Quality Data for the White River, RBOSC MDP Aquatic Monitoring Studies, October 1979 - April 1979

Parameter[1/]	Station 27											
	4/79		5/79		6/79		7/79		8/79		10/79	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium(Ca)	57	60	41	39	49	51	73	74	71	72	72	74
Chloride (Cl)	21	22	0.4	6.7	5.9	13	19	18	31	32	38	35
Fluoride (F)	0.14	0.16	0.12	0.11	0.08	0.08	0.20	0.20	0.23	0.22	0.27	0.27
Magnesium (Mg)	19	20	11	11	15	10	19	19	25	25	26	26
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	0.0	0.01	<0.01	0.01	0.05	0.05	0.08	0.07	0.02	0.02	<0.01	0.01
Phosphorus, Total (P)	0.0	0.02	0.09	0.42	0.08	0.08	0.15	0.09	0.03	0.03	0.02	0.03
Potassium (K)	2.0	2.0	1.5	1.6	1.80	1.1	2.0	2.1	2.4	2.5	2.4	2.4
Silica (Si	6.2	6.4	5.4	5.4	11	11	15	15	16	16	12	13
Sodium (Na	39	39	16	17	14	14	32	33	51	55	54	54
Solids, Total	379	376	211	214	191	191	380	386	494	503	495	507
Sulfate (S)	40	40	16	18	38	32	96	92	152	152	173	171

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-10. Water Quality Data for the White River, RBOSC MDP Aquatic Monitoring Studies, October 1977 -October 1978

Parameter[1/]	Station 29											
	10/77		4/78		6/78		7/78		8/78		10/78	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (Ca)	74	79	72	70	37	37	66	66	69	68	67	72
Chloride (Cl)	46	46	32	32	14	12	39	41	34	35	32	33
Fluoride (F)	0.21	0.19	0.27	0.28	0.14	0.14	0.23	0.24	0.29	0.29	0.21	--
Magnesium (Mg)	31	31	26	27	13	12	19	19	23	23	20	23
Nitrate (N)	<0.2	<0.2	<0.2	<0.2	0.4	0.2	<0.2	<0.2	0.8	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	<0.01	<0.01	0.01	0.01	0.05	0.07	0.02	0.03	<0.01	<0.01	<0.01	<0.01
Phosphorus, Total (P)	<0.01	0.02	0.02	0.02	0.25	0.17	0.03	0.03	0.02	0.04	<0.01	<0.01
Potassium (K)	2.9	3.0	2.2	2.3	2.0	2.0	2.5	2.4	2.5	2.5	2.3	2.2
Silica (Si)	8.1	8.4	6.4	6.2	5.8	5.7	8.5	8.6	8.7	6.8	6.8	7.1
Sodium (Na)	110	100	61	66	35	30	39	39	48	48	48	47
Solids, Total	625	622	490	475	329	302	432	452	458	462	426	430
Sulfate (S)	63	64	50	52	18	14	39	40	47	46	45	46

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-11. Water Quality Data for the White River, RBOSC MDP Aquatic Monitoring Studies, April 1979 - October 1979

Parameter[1/]	Station 29											
	4/79		5/79		6/79		7/79		8/79		10/79	
	A	B	A	B	A	B	A	B	A	B	A	B
Boron (B)	<0.5	0.6	<0.5	1.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Calcium (Ca)	58	62	43	39	49	48	72	73	72	72	71	70
Chloride (Cl)	19	42	16.2	16.2	13	13	19	19	31	32	39	39
Fluoride (F)	0.16	0.17	0.23	0.23	0.18	0.19	0.21	0.21	0.22	0.22	0.29	0.32
Magnesium (Mg)	20	19	21	21	15	14	19	19	25	25	27	27
Nitrate (N)	<0.2	<0.2	4.3	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Phosphorus, Ortho (P)	<0.01	<0.01	0.01	<0.01	0.06	0.05	0.08	0.08	0.02	0.02	<0.01	<0.01
Phosphorus, Total (P)	0.02	0.02	0.03	0.03	0.08	0.08	0.15	0.18	0.03	0.03	0.01	0.02
Potassium (K)	1.9	2.2	2.0	2.0	1.4	1.4	2.0	2.0	2.8	2.7	2.5	2.5
Silica (Si)	5.8	6.2	5.5	5.5	11	11	15	14	17	19	12	12
Sodium (Na)	43	45	77	77	61	55	33	33	64	62	59	60
Solids, Total	397	395	371	425	320	321	384	371	488	482	509	497
Sulfate (S)	40	42	33	33	64	60	103	101	152	155	171	174

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-12. Summary of Water Quality Data for Station 27 on the White River, RBOSC Baseline Studies (October, 1974 through September, 1976).

Parameter[1/]	No. of Analyses	Maximum	Minimum	Mean	S.D.
Calcium (Ca)	24	88	36	69.6	1.16
Chloride (Cl)	24	39	8	31.7	1.35
Fluoride (F)	4	0.30	0.27	0.28	1.42
Magnesium (Mg)	24	34	10	25.1	1.30
Nitrate (N)	24	<0.2	<0.2	<0.2	1.80
Phosphorus, Ortho (P)	24	0.04	0.01	0.01	1.74
Phosphorus, Total (P)	24	0.45	0.02	0.06	2.22
Potassium (K)	24	4.0	1.3	2.3	1.37
Silica (Si)	24	18	9	13.2	1.17
Sodium (Na)	24	76	12	57.4	1.54
Solids, Total	24	629	192	481.5	1.38
Sulfate (S)	24	192	39	154.2	1.31

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted

Table 4-13. Summary of Water Quality Data for Station 29 on the White River, RBOSC Baseline Studies (October 1974 through September 1976).

Parameter[1/]	No. of Analyses	Maximum	Minimum	Mean	S.D.
Calcium (Ca)	24	86	35	66.0	1.14
Chloride (Cl)	24	45	8	33.7	1.23
Fluoride (F)	4	0.59	0.27	0.41	1.06
Magnesium (Mg)	24	37	10	27.0	1.28
Nitrate (N)	24	2.00	0.15	0.26	1.84
Phosphorus, Ortho (P)	24	0.06	0.01	0.02	1.57
Phosphorus, Total (P)	24	0.55	0.02	0.05	2.57
Potassium (K)	24	4.3	1.4	2.3	1.33
Silica (Si)	24	18	10	13.0	1.15
Sodium (Na)	24	138	17	66.7	1.27
Solids, Total	24	699	205	471.5	1.22
Sulfate (S)	24	213	42	157.3	1.24

[1/] Concentration of dissolved fraction in mg/l unless otherwise noted.

quality from baseline condition and no large difference in water quality above and below Yellow Creek since the initiation of project activities. Some decrease in concentration levels of particular parameters such as sulfate, silica, and fluoride was noted in 1978 MDP studies; however, 1979 results were similar to baseline data. Comparison of water quality parameters measured with standards established by the Environmental Protection Agency (EPA, 1976) reveals no apparent problems with the quality of water in streams sampled.

4.2 BIOTIC COMPONENTS

A. Periphyton

1. Objectives

Sensitivity of periphyton to changes in their environment has been well documented (e.g., Lowe 1974). Species composition of the periphyton community and relative abundances of key periphyton species may provide good indicators of potential project effects on Tract C-a vicinity aquatic systems. Periphyton communities are amenable to sampling techniques that provide a quantitative data base for identifying changes in key periphyton populations. Consequently, the study of periphyton communities is an important part of the MDP Monitoring Program. Species composition, relative abundance, biomass, and diversity are the parameters measured to assess the effects of site development on the periphyton community.

2. Methods

The methods followed for collection of these data were described in the RBOSC MDP Monitoring Report 4 (1979).

3. Results and Discussion

A total of 132 taxa was identified from the periphyton samples collected during 1979 monitoring studies. The distribution of taxa among sample stations over all sampling periods is provided in Appendix 4-1. The seasonal changes in species occurrence at each station are displayed in Appendix 4-2. Periphyton enumeration and biomass data are provided for the 1979 Monitoring Program in Appendices 4-3 and 4-4, respectively. Periphyton density and species diversity estimates are provided by sample date for all sampling stations surveyed during 1979 in Appendix 4-5. Biomass estimates for 1979 are presented in Appendix 4-6. The mean densities of dominant taxa (i.e., comprise $\geq$ 1% of the total density) collected during the RBOSC Aquatic Baseline Program (1974-1976) and MDP Monitoring Studies (1978 and 1979) are presented in Table 4-14. Data in this table are organized by station and sampling month. Comparison of species diversity indices and mean biomass for periphyton samples collected during baseline and

Table 4-14. Mean Densities of the Most Abundant Algal Species (>1% of the Total Density[1]) in the Periphyton During RBOSC MDP Studies (1978 and 1979) RBOSC Aquatic Baseline Studies (1974-1976)

Station/Taxa	Density (Units/mm^2)			
Station 13 April	1975	1976	1978	1979
Achnanthes lanceolata	288			
A. spp.	4,481	14,765	94	905
Bicoeca lacustris		631	162	
Fragilaria vaucheriae				364
Gomphonema intricatum		12,929		
Meridion circulare		3,240		
Navicula arvensis			25	
N. cryptocephala vars.	830	2,081	14	
N. pelliculosa		15,230		
Nitzschia capitellata		1,008	23	
N. frustulum	125			
Synedra famelica				78
Phormidium spp.				3,148
Total	6,334	52,868	403	4,633
June				
Achnanthes lanceolata	1	8		
A. spp.	29	200	178	222
Biocoeca lacustris		71	90	
Fragilaria vaucheriae	3		4	52
Gomphonema intricatum	6	10		
Navicula cryptocephala	9	34	9	19
N. heufleri				16
N. pelliculosa	1	15	21	28
N. secreta var. apiculata				12
N. viridula	1	2	14	
N. spp.	5	4		
Nitzschia acicularis	2			
N. dissipata			7	
N. fonticola				152
N. frustulum	6	6		15
N. holsatica				13
N. palea	3		2	
N. spp.				9
Surirella ovata	1		7	13
Lyngbya spp.				10
Phormidium spp..				441
Total	71	355	357	1,021

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
July	1975	1976	1978	1979
Achnanthes spp.	835	10,784	86	5,816
Biocoeca lacustris		600		
Cymbella affinis		4,420		
Fragilaria vaucheriae	80	708		203
Gomphonema intricatum	79	805		
Navicula arvensis	28	402		
N. cryptocephala	192	3,162	2	
N. pelliculosa	172			
N. viridula		538		
Nitzschia capitellata	70	1,377		
N. frustulum	43	362	61	
N. holsatica	57			
N. latens		187	5	
N. palea	55			
Surirella ovata	11	958		
Calothrix spp.		975	2,117	
Total	1,689	26,875	2,329	6,075
August				
Achnanthes lanceolata	203	57		
A. spp.	2,775	2,002	3,310	3,044
Amphora ovalis var. pediculus		47		
Biocoeca lacustris	652	78	2,188	
Cymbella affinis	220	13		
Fragilaria vaucheriae	98			
Gomphonema intricatum	614	27	40	
Naviculua cryptocephala	197	63	91	
N. pelliculosa	199	15	4,297	
Nitzschia denticula	63	5		
N. fonticola				70
N. frustulum	22	14	18	
Lyngbya spp.	980		905	
Phormidium spp.				74
Total	6,171	2,447	11,313	3,247

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
October	1974	1975	1978	1979
Achnanthes lanceolata	653	1,689	158	
A. spp.	5,378	11,312	3,864	14,889
Biocoeca lacustris		3,289		
Cymbella affinis		290		
Gomphonema intricatum	428	1,632	669	
Meridion circulare	281			
Navicula arvensis	281	769		
N. cryptocephala	7,223	2,949	862	
N. pelliculosa		388	1,521	
N. viridula		75	744	
Nitzschia acicularis	79	2,110		
N. capitellata		84	490	
N. frustulum	158	68	213	
N. linearis	214	25		
N. palea	281	606	177	
Surirella ovata		90	508	
Lyngbya spp.	956	124	930	
Phormidium spp.				246
Plectonema spp.			518	
Total	17,356	26,253	11,288	15,417

Station 14 April	1975	1976	1978	1979
Achnanthes lanceolata	247	99	14	160
A. spp.	4,954	573	48	5,735
Biocoeca lacustris		3,471		
Cymbella affinis	199			
Gomphonema intricatum	23	180	300	274
Navicula arvensis	199	177	584	2,590
N. cryptocephala	435	339	363	
N. pelliculosa	154	957	607	315
N. secreta var. apiculata				200
N. viridula	168	9		
Nitzschia capitellata		273	1,642	
N. denticula	1,688	27		
N. frustulum	1,069	48	431	
N. palea	171	27		
Synedra amphicephala	135			
S. famelica				162
S. fasciculata				111
Total	9,929	6,538	4,176	10,163

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
June	1975	1976	1978	1979
Achnanthes lanceolata			0[2]	129
A. spp.	6,390	4,245		1,340
Biocoeca lacustris		6,570		
Cyclotella menegheniana		59		65
Cymbella affinis	553	37		
Diatoma vulgare var. grande				408
Fragilaria sp.				55
Navicula cryptocephala	279	131		77
N. secreta var. apiculata				323
Nitzschia denticula	4,013	157		301
N. fonticola				89
N. frustulum	313	22		
Synedra amphicephala	176	20		
S. famelica				1,198
S. fasciculata				827
S. ulna	255	50		
Merismopedia glauca	1,005			
Total	13,406	11,494		5,451
July				
Achnanthes lanceolata			0[2]	113
A. spp.	8,160	1,547		880
Cymbella affinis	1,481			
C. minuta				33
Cyclotella meneghiniana	7	21		
Fragilaria vaucheriae	108			32
Navicula cryptocephala	315	175		39
N. secreta var. apiculata				279
N. tripunctata		35		
Nitzschia acicularis	180			
N. denticula	2,124	112		47
N. fonticola				48
N. frustulum	73	329		
N. holsatica	729			
Rhopalodia gibba		49		
R. gibberula		63		
Surirella ovata				22
Synedra famelica	360			257

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
	1975	1976	1978	1979
S. fasciculata				86
S. minuscula	658	7		
S. ulna	495			
Unidentified pennate diatoms				44
Plectonema spp.	1,102			
Total	16,171	2,464		2,021
August				
Achnanthes lanceolata	20	56		
A. spp.	3,191	686	35	1,887
Amphora ovalis var. pediculus		70		
Cocconeis placentula		35	1	
Cyclotella meneghiniana	211			
Cymbella affinis	4,140	21		
C. cymbiformis				72
C. microcephala	226			
C. minuta				90
C. ventricosa	208	7	1	
Diatoma tenue var. elongatum				90
D. vulgare var. grande				71
Fragilaria capucina				322
F. vaucheriae				85
Navicula cryptocephala	165	203	5	
N. pelliculosa	14	28	4	
N. secreta var. apiculata				232
Nitzschia capitellata			1	
N. denticula	1,969	21	1	222
N. fonticola				88
N. frustulum	27	203	2	
N. holsatica		811		109
N. palea	14	91	1	
Rhoicosphenia curvata		42		
Rhopalodia gibberula		119		
Synedra amphicephala			1	
S. famelica				992
S. fasciculata				322
S. spp.				71
Unidentified pennate diatom				122
Total	10,467	1,822	51	5,079

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
October	1974	1975	1978	1979
Achnanthes lanceolata	2	3		
A. spp.	641	491	65	131
Cyclotella meneghiniana		10	2	4,395
Cymbella affinis		54		1,362
C. microcephala		22		
C. minuta				123
Fragilaria vaucheriae	4	1	5	166
Gomphonema intricatum			4	110
Navicula cryptocephala	9	20	5	
N. pelliculosa				109
N. secreta var. apiculata				269
Nitzschia denticula				365
N. frustulum	34		5	
N. palea	9	1	9	
N. spp.				163
N. sp. #1				112
Synedra amphicephala	11		6	
S. famelica				1,184
S. fasciculata				362
S. ulna	22		42	
Thalassiosira fluviatilis				140
Unidentified pennate diatom				123
Lyngbya spp.			3	
Total	850	723	162	9,516

Station 20 April	1975	1976	1978	1979
Achnanthes spp.	1,337	6	6,226	
Cymbella affinis	72			
Fragilaria vaucheriae	108	48	10	262
Gomphonema olivaceum	13	9		35
Navicula pelliculosa	518	1,334	21,965	729
Nitzschia capitellate		190	3	
N. fonticola				232
N. frustulum	32	18	1,635	
N. holsatica		80		475
N. microcephala			355	
N. palea	45	84	909	
N. spp.				29
Surirella ovata	243	1,035	52	280
Synedra amphicephala	9	1,350	2	
S. famelica				26
Total	2,439	4,287	31,436	2,182

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
June	1975	1976	1978	1979
Achnanthes spp.	5,011	37	106	177
Bicoeca lacustris		26		
Cyclotella meneghiniana	74	70	20	23
Cymbella ventricosa	61			
Fragilaria vaucheriae				16
Navicula cryptocephala	13	7		8
N. pelliculosa	22	9		46
Nitzschia fonticola				371
N. frustulum	3	414	119	
N. holsatica				8
N. latens		14		13
Surirella ovata	6	12		
Calothrix spp.	19	26	1,030	
Lyngbya spp.	144	9		9
Phormidium spp.				24
Total	5,490	648	1,404	724
July				
Achnanthes spp.	84	36	86	
Cyclotella meneghiniana	24	162	18	15
Cymbella pusilla		21	13	
C. ventricosa	24	3		
	25			
Gomphonema olivaceum				
Mastogloia elliptica		71	2	3
Navicula cryptocephala	111	36	2	
N. pelliculosa	122			
N. viridula	35	99		
Nitzschia fonticola	128	9		22
N. frustulum	64	747	61	
N. holsatica	32	111		2
N. latens		38	5	
N. microcephala	3	15	22	
Synedra pulchella				4
Unidentified pennate diatoms				1
Bulbochaetae spp.				72
Calothrix spp.	2	177	2,117	
Cladophora spp.	2	25		
Total	832	1,443	2,328	126

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
August	1975	1976	1978	1979
Achnanthes spp.	1,132	123	86	20
Cyclotella meneghiniana	4	78	18	63
Cymbella ventricosa	28			
C. sp. #1		82		
Fragilaria capucina				3
Gomphonema intricatum				9
Mastogloia elliptica		157	2	
Navicula cryptocephala	12	250	2	15
N. viridula				7
Nitzschia capitellata		93		
N. fonticola	20			12
N. frustulum	24	3,196	61	
N. holsatica		310		
N. microcephala			22	4
N. palea	42			
N. latens		142	5	
N. spp.				100
Synedra pulchella		63	2	
Calothrix spp.			2,117	
Total	1,309	4,780	2,335	252
October	1974	1975	1978	1979
Achnanthes spp.	7,718	7,629	49	478
Cyclotella meneghiniana	855	60	117	
Cymbella affinis	7,830			
C. pusilla	23	330	3	
Navicula cryptocephala	214	131	6	
N. sp. #1		30	119	
N. viridula		8	74	
Nitzschia frustulum	124	356	295	
N. holsatica			41	
N. latens		27	183	
N. microcephala		4	97	
N. palea	45	203	33	
Surirella ovata			43	
Thalassiosira fluviatilis		4	73	
Calothrix spp.	2,059			
Total	13,996	8,965	1,257	547

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
Station 21 April	1975	1976	1978	1979
Achnanthes lanceolata				8
A.spp.	977	114	807	19
Fragilaria vaucheriae	162	118	4	106
Gomphonema olivaceum	9			11
Navicula cryptocephala	13	26	49	10
N. pelliculosa	3,996	547	15,634	75
Nitzschia capitellata		283	4	
N. fonticola				25
N. frustulum	40	18	851	15
N. holsatica		136		52
N. microcephala			172	
N. palea	58	12	1,791	
N. spp.				9
Surirella ovata	266	1,276	219	124
S. ovalis				54
Synedra amphicephala	9	1,149		
Total	5,645	2,026	19,625	543
June				
Achnanthes spp.	2,142	753	50	22
Cyclotella meneghiniana	86	446	60	24
Cymbella ventricosa	38			
Fragilaria vaucheriae		52		8
Navicula cryptocephala	20	52	13	5
N. pelliculosa	12	22		18
Nitzschia fonticola				225
N. frustulum	180	406	42	5
N. microcephala	43		8	
N. palea	135		3	
N. sp. #1				4
Rhopalodia gibberula			32	
Surirella ovata	5	147	1	
Synedra pulchella	5	125	108	
Calothrix spp.			941	
Dactylococcopsis spp.	9			39
Lyngbya spp.	108	31		
Phormidium spp.				5
Plectonema spp.	596			
Cladophora spp.		273		
Mougeotia spp.			32	
Total	3,405	2,397	1,328	374

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
July	1975	1976	1978	1979
Achnanthes spp.	281	37	46	
Amphora ovalis var. pediculus	192	2	1	
Cyclotella meneghiniana	19	157	45	62
Cymbella pusilla		25	2	
Fragilaria vaucheriae				
Gomphonema olivaceum	97			
Mastogloia elliptica		78	3	
Navicula cryptocephala	158	145	10	
Nitzschia fonticola	291			140
N. frustulom	100	789	120	
N. holsatica	51	12		11
N. microcephala	37	8	50	8
N. palea	59		2	
Rhopalodia gibberula		25	13	
Synedra pulchella				11
S. ulna	142	5		
Calothrix spp.	48	131	3,433	
Lyngbya spp.	456			
Bulbochaetae spp.				284
Cladophora spp.		32		
Total	2,259	1,520	3,764	543
August				
Achnanthes spp.	653	101	7	12
Cyclotella meneghiniana	20	41	74	57
Cymbella pusilla			52	
C. ventricosa	15		52	
Gomphonema intricatum	39			9
G. parvulum				19
Navicula cryptocephala		238	9	12
N. viridula	16		13	
Nitzschia fonticola				174
N. frustulum	98	14,004	55	
N. holsatica	18	244	4	17
N. latens	117	619	2	
N. microcephala		45	42	16
N. spp.				14
N. sp. #1				312
Calothrix spp.	10	15	2,263	
Lyngbya spp.	17		5	
Phormidium spp.				10
Total	1,047	15,538	2,497	669

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
October	1974	1975	1978	1979
Achnanthes spp.	5,996	6,464	3	789
Cyclotella menegniniana	236	9	36	19
Cymbella affinis	9,034			
C. pusilla	113	81	1	
Gomphonema intricatum	11	71	1	
Navicula cryptocephala	45	29	9	13
N. sp. #1		4	76	
N. viridula		8	44	
Nitzschia capitellata			14	
N. fonticola				10
N. frustulum	68	48	188	
N. holsatica			15	
N. latens		4	102	
N. microcephala			49	
N. palea	101	45	8	
N. sp. #1			-	33
Surirella ovata		5	18	
Thalassiosira fluviatilis			36	
Calothrix spp.	540			
Phormidium spp.				25
Total	15,087	6,846	645	906

Station 27 April	1975	1976	1978	1979
Achnanthes spp.	202	102	22	40
Amphora ovalis var. pediculus	360	1,632	8	
Cymbella minuta				19
Epithemia sorex	911	1,371		110
Gomphonema olivaceum	675	634	2,944	292
Navicula cryptocephala	2,328	1,145	401	44
N. pelliculosa	79		1,951	35
N. tripunctata	1,463	816	26	
N. viridula	2,014	4,477	402	44
Nitzschia dissipata	1,957	1,519	258	29
N. fonticola				16
N. frustulum	168	997	18	15
N. holsatica				15
Rhoicosphenia curvata				19
Surirella ovata	540	57	18	
Calothrix spp.	124	1,020		
Phormidium spp.				143
Total	13,790	14,604	6,155	885

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
June	1975	1976	1978	1979
Achnanthes spp.	306	181	0[2]	0[2]
Amphora ovalis var. pediculus	1,914	2,278		
Cymbella sinuata	589	125		
C. ventricosa	65	249		
Epithemia sorex		234		
Fragilaria vaucheriae		272		
Gomphonema olivaceum		1,133		
Navicula cryptocephala	121	2,289		
N. pelliculosa	2,090	159		
N. tripunctata	2	567		
N. vaucheriae	252			
N. viridula		467		
Nitzschia dissipata	50	1,802		
N. frustulum	263	1,496		
Calothrix spp.		137		
Lyngbya spp.	36	771		
Total	5,742	13,460		
July				
Achnanthes spp.	30	45	180	17
Amphora ovalis var. pediculus	365	5,269	569	
A. perpusilla				42
Biocoeca lacustris	233			
Cymbella affinis	52		114	
C. minuta				16
C. sinuata	45	87	146	
Diatoma vulgare	270			18
Epithemia sorex	60	742	297	
Gomphonema olivaceum	217	19	58	90
Navicula arvensis				12
N. cryptocephala	907	373	111	63
N. pelliculosa				37
N. salinarum var. intermedia	89	15	106	11
N. tripunctata	217	219	31	20
Nitzschia chasei	142	98		
N. dissipata	232	94	160	
N. fonticola				50
N. frustulum	157	117	195	

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
	1975	1976	1978	1979
N. holsatica	352		50	29
Rhoicosphenia curvata				12
Synedra ulna	502		8	77
Calothrix spp.	30	3,241	2,994	14
Lyngbya spp.	2,208		1,385	332
Total	6,577	10,610	6,622	945
August				
Achnanthes spp.		102	10	
Amphora ovalis var. pediculus	2,543	425	14	
A. perpusilla				492
Cocconeis pediculus		589	26	
C. placentula	315		16	13
Diatoma vulgare	765			
Epithemia sorex	3,774	1,796	334	152
Gomphonema intricatum		255	3	
G. ventricosa	1,148			
Navicula cryptocephala	2,183	346	7	
N. notha		181		15
N. salinarum var. intermedia	1,328		3	
Nitzschia chasei	878			
N. dissipata	2,700			118
N. frustulum	2,115	108	12	
N. holsatica		91	2	
N. spp.				40
Unidentified pennate diatoms				30
Calothrix spp.	68	2,692	1,194	74
Lyngbya spp.	697		49	152
Total	22,171	7,107	1,717	1,181

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
October	1974	1975	1978	1979
Achnanthes spp.	34	169	62	91
Amphora ovalis var. pediculus	23	495	6	
A. perpusilla				20
Cocconeis pediculus	168	23	16	20
C. placentula				21
Cymbella affinis				15
C. sinuata			15	
Epithemia sorex	5,411	7,594		460
Gomphonema intricatum	22	113	24	
G. olivaceum	259	79	46	
G. tenellum				30
Navicula cryptocephala	259	1,969		17
N. pelliculosa			23	
N. salinarum var. intermedia	315	776		67
N. tripunctata	113	787		21
Nitzschia chasei		405		
N. dissipata	146	2,025	6	
N. fonticola				17
N. frustulum	90	450	6	
N. holsatica			8	
N. spp.				87
Rhoicosphenia curvata				60
Surirella ovata		810		
Unidentified pannate diatoms				30
Calothrix spp.	1,103	124		141
Lyngbya spp.	596	1,317		192
Phormidium spp.				39
Total	11,062	17,720	245	1,393

Station 29 April	1975	1976	1978	1979
Achnanthes lanceolata				3
A. spp.	731	38	22	104
Amphora ovalis var. pediculus	79	874	3	
A. perpusilla				3
Cocconeis placentula				2
Cymbella sinuata		180		
Epithemia sorex	1,192	117		
Fragilaria vaucheriae				5

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
	1975	1976	1978	1979
Gomphonema olivaceum	574	1,115	1,768	15
Navicula cryptocephala	889	540	545	2
N. pelliculosa	34	82	1,977	28
N. tripunctata	292	204	78	
N. viridula	1,204	2,737	560	13
Nitzschia dissipata	1,474	986	590	
N. fonticola				3
N. frustulum	101	187	103	
Surirella ovata	123	243	4	
Calothrix spp.	979	7		
Lyngbya spp.	259			
Plectonema spp.	250			
Total	9,294	7,647	5,740	193
June				
Achnanthes spp.	27	408	0[2]	0[2]
Amphora ovalis var pediculus	400	487		
Biocoeca lacustris		669		
Calothrix spp.	36	4,579		
Cyclotella meneghiniana	40			
Cymbella sinuata	166	181		
Gomphenema olivaceum	9	782		
Lyngbya spp.	36			
Navicula cryptocephala	128	1,122		
N. pelliculosa	61	317		
N. tripunctata	32	295		
Nitzschia dissipata	29	816		
N. frustulum	488	2,312		
Total	1,571	13,160		
July				
Achnanthes minutissima	135	45	6	8
Amphora ovalis var. pediculus	2,129	306	6	
A. perpusilla				44
Bicoeca lacustris	120		18	
Cocconeis pediculus		329		
C. placentula		91	22	
Cyclotella meneghiniana				3
Cymbella minuta				5
C. sinuata	307	170	8	5

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
	1975	1976	1978	1979
Epithemia sorex	127	5,315	3	
Fragilaria vaucheriae	143	11		4
Gomphonema intricatum	82	283		
G. olivaceum	420	34	17	21
Navicula cryptocephala	398	328	2	22
N. pelliculosa				7
N. tripunctata	22	79		4
N. viridula				5
Nitzschia dissipata	306	11	3	
N. fonticola				12
N. frustulum	135	79	22	
N. holsatica	239		1	17
N. spp.				
Synedra ulna				
Calothrix spp.	52	2,709	58	
Lyngbya spp.	5,160		80	75
Phormidium spp.				22
Cladophora spp.	1	33	26	
Total	10,919	3,328	289	290
August				
Achnanthes spp.	7	67	69	12
Amphora ovalis var. pediculus	120	33	11	
A. perpusilla				21
Cocconeis pediculus		707	73	
C. placentula	34	115	49	70
Cyclotella meneghiniana		133		10
Cymbella affinis	105	23	6	
C. sinuata				6
Epithemia sorex	3,747	2,517	864	54
Gomphonema olivaceum	79	13	22	21
G. intricatum		622		
G. ventricosa	94			
Navicula cryptocephala	476	140	28	
N. salinarum var. intermedia	712	125	6	
N. tripunctata	128	214		
Nitzschia dissipata	739	84		
N. fonticola				20
N. frustulum	409	172	23	
N. spp.				6

Table 4-14 (Continued)

Station/Taxa	Density (Units/mm^2)			
	1975	1976	1978	1979
Rhoicosphenia curvata				3
Calothrix spp.	75	2,083	890	11
Lyngbya spp.	795	6	30	3
Cladophora spp.		41	90	
Total	8,071	7,582	2,219	253
October	1974	1975	1978	1979
Achnanthes spp.	956	197	197	185
Amphora ovalis var. pediculus	11	2,043	2	
A. perpusilla				13
Cocconeis pediculus	90		2	
C. placentula			9	27
Cymbella affinis	371	57		22
C. sinuata		338	10	35
Epithemia sorex	2,486	13,231	18	194
Gomphonema intricatum		6	152	55
G. olivaceum	158	113	24	
Navicula cryptocephala	889	807	4	11
N. pelliculosa			73	20
N. salinarum var. intermedia	338	452	1	
N. tripunctata	102	198		14
Nitzschia dissipata	371	1,146	8	
N. fonticola				35
N. frustulum	382	587	23	
N. holsatica	45	34	18	
N. palea	113	28		
N. spp.				114
Rhoicosphenia curvata				29
Unidentified pennate diatoms				22
Lyngbya spp.	1,170	1,962	13	53
Oscillatoria spp.	799	96		
Mougeotia spp.				12
Total	8,732	21,830	554	906

[1] Total density figures also include density estimates of less abundant periphyton not listed in table.

[2] No samples collected due to high water conditions.

MDP studies is provided in Tables 4-15 and 4-16, respectively. Since samples were not collected in May prior to 1979, May data for these samples are not presented in the above tables; refer to the Appendices for these data.

A great deal of variation in periphyton population parameters exists for samples collected at each station during a particular month for different years. Periphyton community structure as described by parameters such as density, diversity, and biomass, is determined by various factors such as light, temperature, current velocity, substrate, and turbidity that vary both seasonally and annually. Since annual variation may generate a completely different set of environmental conditions for a particular station during a particular month from year to year, substantial annual fluctuations on periphyton community structure may be evident. For instance, spring run-off and summer warming may occur at different times each year resulting in a completely different set of dominant periphyton species for the initial periphyton sample each year. While an overview of data collected for a particular year and a comparison with previous year's data may provide some indication of the general trend of periphyton community structure changes in the study area, evaluation of seasonal changes within a given year may be more appropriate to determining the effect of environmental changes on specific periphyton parameters. The latter is emphasized in the discussion of 1979 data collected at each sample station.

Generally, 1979 periphyton monitoring data were characterized by lower densities, diversities, and biomass estimates when compared to previous year's data. At Station 13, where recent mine dewatering activities would have its greatest effect, mean total periphyton density in 1979 was not appreciably different than in previous RBOSC study years. Excluding 1976 data, which fluctuated greatly, the general trend in periphyton densities at this and other monitoring locations is to decrease from high early spring levels to low densities in May and June, presumably from run-off effects, to a fairly steady increase through summer and fall. The dominant taxon in the periphyton of both baseline and monitoring samples at Station 13 was Achnanthes spp. (largely Achnanthes minutissima). Taxa dominating during the monitoring studies but not in the baseline studies were the blue-green algae, Phormidium spp. in April, May, and June, 1979 and Calothrix spp. in July, 1978. During spring and early summer of 1979 Phormidium spp. was the major constituent of the periphyton. Through the following months,

Table 4-15. Comparison of Diversity Indices of Periphyton During RBOSC MDP Studies (1978 and 1979) and RBOSC Aquatic Baseline Studies (1974-1976)

Location	Month	Index	Baseline			MDP	
			1974	1975	1976	1978	1979
Station 13	April	Shannon	--	1.57	2.24	2.77	1.03
		Evenness	--	0.40	0.52	0.71	0.33
		No. of Species	--	15	20	14	23
	June	Shannon	--	2.55	1.92	1.94	1.80
		Evenness	--	0.76	0.58	0.70	0.57
		No. of Species	--	10	10	7	23
	July	Shannon	--	2.73	2.93	--	0.21
		Evenness	--	0.66	0.67	--	0.82
		No. of Species	--	18	21	--	13
	August	Shannon	--	1.17	1.37	1.70	0.33
		Evenness	--	0.29	0.33	0.49	0.15
		No. of Species	--	17	17	12	9
	October	Shannon	2.49	2.66	--	2.77	0.20
		Evenness	0.58	0.61	--	0.67	0.09
		No. of Species	19	21	--	17	10
Station 14	April	Shannon	--	2.41	2.43	2.44	1.47
		Evenness	--	0.56	0.54	0.63	0.42
		No. of Species	--	--	23	15	32
	June	Shannon	--	2.05	1.36	--	2.42
		Evenness	--	0.47	0.34	--	0.63
		No. of Species	--	21	16	--	45
	July	Shannon	--	2.73	2.93	--	2.11
		Evenness	--	0.66	0.67	--	0.58
		No. of Species	--	18	21	--	38
	August	Shannon	--	1.78	3.36	1.79	2.31
		Evenness	--	0.44	0.69	0.63	0.65
		No. of Species	--	16	29	7	35
	October	Shannon	1.37	1.55	--	2.58	2.01
		Evenness	0.45	0.43	--	0.73	0.58
		No. of Species	9	12	--	12	32

Table 4-15 (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979
Station 20	April	Shannon	--	1.74	2.17	1.22	1.92
		Evenness	--	0.46	0.58	0.36	0.57
		No. of Species	--	13	15	11	29
	June	Shannon	--	0.58	1.98	1.47	1.63
		Evenness	--	0.17	0.56	0.46	0.48
		No. of Species	--	12	12	10	31
	July	Shannon	--	3.48	2.70	0.74	1.50
		Evenness	--	0.76	0.64	0.27	0.43
		No. of Species	--	24	19	7	33
	August	Shannon	--	1.04	2.31	0.78	2.06
		Evenness	--	0.29	0.52	0.24	0.53
		No. of Species	--	12	21	9	50
	October	Shannon	1.77	1.28	--	3.25	0.65
		Evenness	0.51	0.34	--	0.76	0.22
		No. of Species	11	13	--	18	19
Station 21	April	Shannon	--	--	--	--	2.40
		Evenness	--	--	--	--	0.64
		No. of Species	--	--	--	--	42
	June	Shannon	--	1.57	2.59	1.81	1.63
		Evenness	--	0.44	0.64	0.48	0.46
		No. of Species	--	12	17	14	34
	July	Shannon	--	2.90	2.60	0.58	1.44
		Evenness	--	0.72	0.58	0.19	0.43
		No. of Species	--	17	23	9	28
	August	Shannon	--	2.04	1.97	0.72	1.71
		Evenness	--	0.51	0.54	1.43	0.53
		No. of Species	--	11	13	12	26
	October	Shannon Index	1.45	0.48	--	3.12	0.65
		Evenness	0.44	0.14	--	0.78	0.24
		No. of Species	10	10	--	16	15

Table 4-15 (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979
Station 27	April	Shannon	--	1.47	2.36	0.93	2.36
		Evenness	--	0.42	0.60	0.27	0.67
		No. of Species	--	12	16	11	34
	June	Shannon	--	2.48	3.32	--	--
		Evenness	--	0.65	0.74	--	--
		No. of Species	--	14	23	--	--
	July	Shannon	--	3.44	1.89	2.52	2.64
		Evenness	--	0.73	0.49	0.57	0.65
		No. of Species	--	26	15	22	59
	August	Shannon	--	3.38	2.82	1.37	2.05
		Evenness	--	0.66	0.63	0.42	0.58
		No. of Species	--	34	23	10	35
	October	Shannon	1.87	2.89	--	2.99	2.44
		Evenness	0.44	0.61	--	0.79	0.68
		No. of Species	18	26	--	14	36
Station 29	April	Shannon	--	3.25	2.77	2.09	1.77
		Evenness	--	0.69	0.63	0.61	0.51
		No. of Species	--	27	21	11	32
	June	Shannon	--	2.80	3.06	--	--
		Evenness	--	0.67	0.69	--	--
		No. of Species	--	19	21	--	--
	July	Shannon	--	2.72	2.05	2.91	2.67
		Evenness	--	0.57	0.52	0.74	0.71
		No. of Species	--	26	16	16	43
	August	Shannon	--	2.44	3.09	2.20	2.35
		Evenness	--	0.51	0.64	0.57	0.66
		No. of Species	--	27	28	16	35
	October	Shannon	--	2.65	2.17	2.39	2.61
		Evenness	--	0.61	0.47	0.62	0.72
		No. of Species	--	20	24	15	38

Table 4-16. Mean Periphyton Biomass (Ash-Free Dry Weight) During RBOSC MDP Studies (1978-1979) and RBOSC Aquatic Baseline Studies (1974-1976)

Station	Month	Biomass (mg/cm^2) 1975	1976	1978	1979
13	April	1.018	2.594	0.696	1.737
	June	0.726	0.260	0.588	0.801
	July	2.522	1.708	-	0.571
	August	1.032	0.974	0.688	0.414
	October	2.954	2.354	2.818	1.204
14	April	27.182	1.234	2.940	0.992
	June	1.210	0.712	-	2.383
	July	12.566	0.644	-	0.989
	August	1.086	0.830	2.276	1.547
	October	0.470	0.462	1.481	2.614
20	April	1.484	0.846	1.572	0.783
	June	0.572	2.272	2.222	1.997
	July	0.816	1.632	3.294	0.285
	August	0.704	4.854	2.162	0.865
	October	3.367	0.926	2.094	0.397
21	April	2.136	0.754	6.008	1.641
	June	9.390	6.494	1.922	1.960
	July	0.910	7.710	6.578	2.734
	August	0.896	2.356	5.044	0.841
	October	3.628	1.078	6.988	0.571
27	April	8.862	6.486	1.040	2.465
	June	1.040	1.358	-	-
	July	19.218	4.786	1.602	1.507
	August	7.874	7.874	3.728	2.575
	October	15.382	9.460	0.148	6.545
29	April	6.936	2.330	1.124	0.694
	June	3.250	2.720	-	-
	July	12.396	9.158	0.364	0.722
	August	6.794	11.388	1.860	0.971
	October	9.502	7.494	0.312	10.243

the periphyton community was almost completely comprised of Achnanthes spp. This paucity of different taxa in 1979 is reflected in the Shannon diversity indices. In every month sampled, the diversity index was considerably lower in 1979 than during the baseline studies or the 1978 monitoring data. The 1979 biomass estimates generally followed the same trend as total density; however, values tended to be lower when the periphyton communities were dominated by the minute alga, Achnanthes spp. No definite differences were apparent when comparing 1979 biomass determinations with 1978 monitoring data or with previous baseline studies data.

At Station 14, total periphyton densities varied widely seasonally and annually. The nature of this site with its pond-like habitat, limited rock substrates, and occasional disturbances by livestock and farm machinery make it difficult to assess changes and impacts. No trends in total mean density were apparent except in fall 1979 when densities were greater than fall samples in previous years. The taxa dominating at different times in the year and during different years varied. During the 1979 monitoring studies, the dominating periphyton taxa included Achnanthes spp., Navicula arvensis, Synedra famelica, Synedra fasciculata, Diatoma vulgare var. grande, Cyclotella meneghiniana, and Cymbella affinis. These taxa, in different combination, have been generally characteristic of all samples taken at Station 14 during baseline and monitoring studies.

At the Yellow Creek Stations, 20 and 21, total mean density values were lower in 1979 than in previous years. Densities have been fairly constant with little seasonal variation except when density pulses were observed in spring, 1976 and fall, 1974 and 1975. In 1979, the upstream station, Station 20, showed higher densities during spring and early summer while Station 21 evidenced higher densities during summer and fall. Diversity at the two Yellow Creek stations followed similar patterns each year. Visual comparison of monitoring and baseline diversity data showed no obvious differences or trends. As with the density data, 1979 periphyton biomass was generally lower than that measured in previous years. Because of differences in periphyton community composition, the higher spring and early summer densities at Station 20 were not reflected in the biomass weights. Station 21 generally had higher biomass.

At Station 20, the 1979 periphyton communities changed from a spring assemblage dominated by Navicula pelliculosa and various Nitzschia species to an early

summer assemblage dominated by Nitzschia fonticola and Achnanthes spp. In July, the community became dominated by an immature green alga, Bulbochaetae sp., and co-dominated by Nitzschia fonticola and Cyclotella meneghiniana. By August, the Bulbochaetae sp. had become less abundant and Nitzschia spp., Cyclotella meneghiniana, and Achnanthes spp. dominated. Achnanthes spp. dominated periphyton assemblage in the fall. During 1978 monitoring efforts, the spring assemblage was similar to the one observed in 1979. The summer community, however, was dominated by a blue-green alga, Calothrix spp., which was the major constituent over a three-month period.

At Station 21, the 1979 periphyton communities were somewhat similar to those found at Station 20. The spring community was comprised of Surirella ovata, Fragilaria vaucheriae, and Navicula pelliculosa. The summer assemblage was dominated by Bulbochaetae sp. and the fall dominated by Achnanthes spp. The 1978 monitoring effort at Station 21 yielded results similar to that found at Station 20 with spring and fall diatom communities and the summer community again dominated by Calothrix sp.

Comparing the periphyton communities of the baseline and monitoring studies at Station 20 and 21, the spring and fall communities appear to be dominated by a group of diatoms whose relative abundance varies annually. The summer trend of dominance by green algae and blue-green algae has increased in the monitoring phase, 1978-1979.

Periphyton was not collected at Stations 27 and 29 on the White River during May or June, 1979 because of high water conditions. At the White River stations, periphyton density was lower during the 1978-1979 monitoring studies than during the baseline studies and generally lowest in the 1979 samples. Mean total periphyton densities were generally higher at the upstream station when comparing data for the two stations in 1979.

At the upstream location, Station 27, the spring periphyton community was characterized in 1979 by Gomphonema olivaceum, Phormidium sp., and Epithemia sorex. In July, after substrate scouring by spring floods, Lyngbya spp. dominated and densities of the diatoms Gomphonema olivaceum, Synedra unla, and Navicula cryptocephala were low. As the periphyton community recovered from flood

scouring, Amphora perpusilla, Epithemia sorex, Lyngbya spp., and Nitzschia dissipata increased in numbers at Station 27. In 1979 highest total densities were observed at this Station in October; at this time the periphyton community was dominated by Epithemia sorex with the blue-green algae, Lyngbya spp. and Calothrix spp., also abundant. The seasonal trends observed in 1979 were somewhat similar to those seen in previous sample years although trends appeared out of phase by about a month, probably due to the timing and duration of spring run-off.

Some notable differences that occurred in the composition of the 1979 periphyton communities at this station, as opposed to earlier years, included a decreased dominance of Calothrix sp. from the summer of 1979 and a very different October, 1978 community. Also spring community compositions observed during the baseline studies varied from those found in monitoring studies. At Station 27 in 1979, the Shannon diversities were similar to the 1978 values. The comparison of MDP diversity indices with those calculated for baseline studies indicate similar results although they also appear about a month out of phase, again, probably due to annual fluctuation in the extent and timing of spring run-off. As with the densities at Station 27, biomass determinations were generally lower during the 1978-1979 monitoring studies when compared to baseline results. The periphyton biomass varied seasonally during all sampling years, generally showing a decrease after spring flood, rising to a maximum during the summer, and then decreasing again. In 1979, however, the maximum previously reached during summer occurred in the fall.

At Station 29,on the White River downstream from the confluence with Yellow Creek, the periphyton composition differed somewhat from Station 27. The spring community was dominated by Achnanthes spp. In July, Lyngbya spp. and Amphora perpusilla dominated and in August, Cocconeis placentula and Epithemia sorex dominated. By October, 1979, the periphyton communities at both White River stations were similar with Station 29 dominated by Epithemia sorex, Achnanthes sp., and Nitzschia spp. As with Station 27, the 1979 data at Station 29 were similar to that recorded for previous years with a few notable differences. During the summer of 1979 and 1978, Calothrix sp. was of greater importance and the fall, 1978 periphyton community was very different from the other fall sampling. The Shannon diversity indices at Station 29 were similar in 1978 and 1979. As with the upstream White River station, diversity determinations during MDP studies

seemed to be about a month or more out of phase with the baseline studies. Diversity trends apparent in 1979 at Station 29 were the same as described for Station 27.

Periphyton biomass was generally lower during the 1978-1979 monitoring studies at Station 29. Seasonal variation was similar to that described for Station 27. During the monitoring studies, biomass at the downstream station generally was lower. An upstream-downstream difference in biomass was less obvious during the baseline studies.

In summary, changes may have occurred in the periphyton communities since the initiation of baseline studies that cannot be accounted for by seasonal variations. Also, examination of changes in physical parameters such as temperature and current velocity are not consistent with observed changes in periphyton community structure. At Station 13 in 1979, the diversity decreased and the spring and early summer communities became dominated by blue-green algae to an extent that had not been seen before. At Stations 20 and 21 periphyton density and biomass decreased in 1979, and in 1978 and 1979 the summer periphyton community showed blue-green and green algae increasing in importance as represented by Calothrix spp. and Bulbochaetae spp. At Stations 27 and 29, the 1978 and 1979 data showed depressed densities and biomass values and in 1979 the upstream station had the higher densities and biomass weights.

Generally, the stations showing high conductivity (Stations 13, 14, 20, and 21) showed species combinations more attuned to higher osmotic levels. The communities found at the "more fresh" water stations (Stations 27 and 29) were comprised of more characteristic fresh-hard water taxa such as Epithemia sorex, Gomphonema olivaceum, and Nitzschia dissipata (Lowe 1974).

The changes noted at Station 13 may be due in part to an increase in turbidity resulting from dewatering activities. Some blue-green algae have been shown to be favored by increased turbidity (Hutchinson 1967). In a model of effects of oil shale retorting, water discharge of high dilutions were shown to depress growth and increase the relative abundance of bacteria and green algae (Russell 1979). Although retorting has not begun, a depression of growth and increased

bacterial growth has been noted at Station 13. Changes in species composition and reduced diversity, as indicated by the Shannon indices, indicate that project activities may have had some effect on the periphyton community at Station 13. It is difficult to assess whether the changes that have occurred at other stations are due to Tract C-a activities or natural variation in environmental conditions. It is most likely that natural variation is responsible since Yellow Creek flows underground for a considerable distance upstream from Station 20 and hydrologic tests have shown that, as a result, Tract C-a surface waters may not reach lower Yellow Creek or the White River (Section 5.0 Hydrology). Another strong argument in favor of natural variation is that Station 27 on the White River, upstream from any project influence, has shown similar changes in periphyton density, biomass, and species diversity as the other stations. In 1979, Station 27 did indicate higher density and biomass values than the White River downstream station (Station 29); a possible outcome of surface runoff impacts. However, since surface waters originating from Tract C-a environs are either filtered or diverted in their underground flow on Yellow Creek, it is unlikely that any changes in periphyton communities in the White River or lower Yellow Creek are due to project activities.

B. Benthos

1. Objectives

Benthic macroinvertebrates constitute the major component of the secondary trophic level in aquatic ecosystems on and near Tract C-a. Their limited mobility and well-documented susceptibility to physical and chemical changes in their environment make them an important element of the MDP Monitoring Program. Data collected on benthos species composition, relative abundance, and diversity at all sampling stations will permit the evaluation of development activity on benthos as well as identification of potential impacts on other components of the aquatic system.

2. Methods

The methods used in collecting these data were described in RBOSC MDP Monitoring Report 4 (1979).

3. Results and Discussion

A total of 87 taxa was identified from macroinvertebrate samples collected during 1979 monitoring studies. The distribution of taxa among sample stations over all sampling periods is provided in Appendix 4-7. The seasonal changes in species occurrence at each station are displayed in Appendix 4-8. Macroinvertebrate enumeration data are provided by sample date for the 1979 Monitoring Program in Appendix 4-9. Macroinvertebrate density and species diversity calculations are presented for all sampling stations by sampling date in Appendix 4-10.

The mean densities of dominant macroinvertebrate taxa collected during RBOSC Aquatic Baseline Program (1974-1976) and MDP Monitoring Studies (1978-1979) are presented in Table 4-17. Data in the table are organized by station and sampling date. Comparison of species diversity indices collected during baseline and MDP studies are provided in Table 4-18. Results are discussed by sampling station below.

Table 4-17. Major Benthic Macroinvertebrate Taxa Observed During RBOSC MDP Studies (1978-1979) and RBOSC Aquatic Baseline Studies (1974-1976)

Station/Taxa	Density (Units/m^2)			
Station 13 April	1975	1976	1978	1979
Nematoda	241	24	42	6
Oligochaeta	18,190	18	150	42
Ephemeroptera	2,688	139	--	--
Plecoptera	91	24	--	--
Coleoptera	--	--	6	--
Diptera [1]	476	24	12	6
Chironomidae	10,896	1,961	66	30
Total	21,686	2,190	276	84
June				
Nematoda	36	--	6	0
Oligochaeta	48	--	18	163
Diptera	78	272	12	6
Chironomidae	12	153	6	12
Total	174	425	42	181
July				
Nematoda	--	30	--	--
Oligochaeta	30	109	6	283
Ephemeroptera	54	422	--	--
Plecoptera	--	60	--	--
Diptera	24	222	6	12
Chironomidae	102	2,819	42	12
Total	210	3,662	54	307
August				
Nematoda	42	48	--	6
Oligochaeta	--	935	54	638
Ephemeroptera	1,267	3,445	6	--
Plecoptera	935	404	--	--
Diptera	1,110	620	6	--
Chironomidae	1,507	2,697	36	30
Total	4,861	8,149	102	674

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
October	1974	1975	1978	1979
Nematoda	382	--	--	--
Oligochaeta	14,551	66	1,617	385
Ephemeroptera	5,358	66	12	126
Plecoptera	753	1,478	72	788
Diptera	7,063	416	6	150
Chironomidae	38,373	409	138	54
Total	66,480	2,435	1,845	1,503
Station 14 April	1975	1976	1978	1979
Nematoda	252	187	--	6
Oligochaeta	3,094	295	921	1,456
Ephemeroptera	1,199	36	--	18
Plecoptera	--	6	--	--
Coleoptera	--	42	126	--
Diptera	666	235	66	30
Chironomidae	59,836	16,531	3,441	632
Total	65,047	17,332	4,554	2,142
June				
Nematoda	119	458	150	12
Oligochaeta	30	241	1,356	3,664
Ephemeroptera	1,021	--	--	--
Coleoptera	15	284	--	48
Trichoptera	--	--	--	6
Diptera	770	3,723	2,219	66
Chironomidae	1,569	2,450	1,144	2,311
Total	3,523	7,156	4,869	6,107
July				
Nematoda	385	36	18	48
Oligochaeta	44	1,345	6,260	7,690
Ephemeroptera	30	6	60	78
Hemiptera	15	--	6	--
Coleoptera	252	779	132	--

Table 4-17 (Continued)

Station/Taxa	Density (Units/m²)			
	1975	1976	1978	1979
Trichoptera	--	--	--	12
Diptera	385	1,394	1,146	896
Chironomidae	6,689	2,262	1,330	2,347
Total	7,800	3,560	8,952	11,071
August				
Nematoda	74	6	--	78
Oligochaeta	444	826	3,379	10,909
Ephemeroptera	1,673	18	--	6
Plecoptera	--	--	--	
Coleoptera	401	--	--	
Hemiptera	--	12	--	
Diptera	133	241	57	962
Chironomidae	29,084	452	226	8,141
Total	31,809	1,555	3,662	20,096
October	1974	1975	1978	1979
Nematoda	15	--	6	199
Oligochaeta	15	1,010	292	8,953
Ephemeroptera	2,486	118	--	48
Plecoptera	--	30	--	--
Coleoptera	--	44	6	--
Hemiptera	89	15	--	--
Diptera	311	162	58	2,046
Chironomidae	4,071	1,138	596	1,444
Amphipoda	--	29	13	--
Total	6,987	2,546	971	12,690
Station 20 April	1975	1976	1978	1979
Nematoda	145	253	289	--
Oligochaeta	884	2,341	222	12
Odonata	12	--	--	--
Diptera	4,157	97	3,156	84
Chironomidae	5,750	1,001	3,322	403
Total	10,948	3,692	6,989	499

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
June	1974	1975	1978	1979
Nematoda	60	91	18	--
Oligochaeta	60	30	--	12
Ephemeroptera	--	--	--	30
Coleoptera	6	--	18	6
Diptera	489	2,370	2,930	511
Chironomidae	271	676	1,405	542
Total	886	3,167	4,571	1,101
July				
Nematoda	151	127	30	--
Oligochaeta	977	6	--	12
Ephemeroptera	--	18	--	
Odonata	6	42	150	
Coleoptera	24	133	60	6
Diptera	567	2,801	633	2,412
Chironomidae	54	1,725	974	289
Total	1,779	4,852	1,847	2,719
August				
Nematoda	127	108	36	--
Oligochaeta	84	1,448	--	24
Ephemeroptera	36	24	699	--
Odonata	--	24	66	--
Coleoptera	91	--	72	54
Diptera	181	4,730	2,321	18
Chironomidae	42	1,061	1,264	1,991
Total	561	7,395	4,458	2,087
October				
Nematoda	--	833	6	--
Oligochaeta	63	1,955	42	72
Ephemeroptera	--	1,152	12	
Odonata	25	36	6	
Coleoptera	6	6	--	6
Trichoptera	--	--	--	18
Diptera	144	1,611	651	867
Chironomidae	1,127	409	1,893	2,004
Total	1,365	6,002	2,610	2,966

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
Station 21 **April**	1975	1976	1978	1979
Nematoda	66	290	114	--
Oligochaeta	12	271	295	6
Ephemeroptera	6	--	--	
Odonata	--	--	--	
Coleoptera	--	54	--	
Diptera	1,623	338	4,515	54
Chironomidae	779	754	2,821	193
Total	2,486	1,707	7,745	253
June				
Nematoda	24	356	162	--
Oligochaeta	247	332	54	--
Ephemeroptera	6	--	--	--
Odonata	--	6	--	--
Coleoptera	12	314	--	6
Diptera	3,197	537	1,998	367
Chironomidae	1,796	6,649	1,271	511
Total	5,282	8,194	3,485	884
July				
Nematoda	18	163	271	--
Oligochaeta	36	694	271	12
Ephemeroptera	--	91	96	--
Odonata	--	--	18	--
Coleoptera	12	561	42	24
Diptera	688	374	898	2,316
Chironomidae	253	911	4,091	969
Total	1,007	2,794	5,687	3,321

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
August	1975	1976	1978	1979
Nematoda	6	36	301	--
Oligochaeta	--	2,654	186	132
Ephemeroptera	--	54	36	--
Odonata	30	12	6	--
Coleoptera	127	--	6	12
Diptera	102	84	5,928	944
Chironomidae	235	84	1,246	1,769
Total	500	2,924	7,709	2,857
October	1974	1975	1978	1979
Nematoda	--	6	6	--
Oligochaeta	150	--	--	241
Ephemeroptera	19	66	12	
Odonata	--	36	--	
Coleoptera	--	6	6	6
Trichoptera	6	--	--	24
Diptera	417	874	2,253	1,270
Chironomidae	2,084	464	2,038	626
Total	2,676	1,452	4,315	2,167
Station 27 April	1975	1976	1978	1979
Oligochaeta	477	59	1,129	111
Ephemeroptera	280	1,698	2,527	513
Plecoptera	13	78	64	13
Odonata	--	--	--	6
Coleoptera	--	--	--	--
Trichoptera	13	85	233	--
Diptera	--	13	13	--
Chironomidae	516	555	608	13
Total	1,299	2,488	4,574	656

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
July	1975	1976	1978	1979
Oligochaeta	40	378	45	7
Ephemeroptera	--	2,835	433	1,157
Plecoptera	--	--	6	26
Coleoptera	--	--	--	20
Trichoptera	--	47	19	312
Diptera	34	93	96	40
Chironomidae	--	33	77	247
Total	74	3,386	6,761	814
August				
Oligochaeta	572	599	26	65
Ephemeroptera	151	1,238	1,390	5,751
Plecoptera	--	65	--	--
Odonata	--	--	--	13
Trichoptera	34	456	409	845
Diptera	13	72	214	13
Chironomidae	330	438	122	331
Total	1,100	2,868	2,161	7,018
October	1974	1975	1978	1979
Oligochaeta	250	644	52	1,267
Ephemeroptera	402	1,322	564	507
Plecoptera	38	143	12	39
Trichoptera	163	508	162	124
Diptera	6	46	13	26
Chironomidae	853	685	6	1,261
Total	1,712	3,348	809	3,224

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
Station 29 April	1975	1976	1978	1979
Nematoda	117	20	13	7
Oligochaeta	1,602	853	648	292
Ephemeroptera	742	605	480	624
Plecoptera	91	157	77	52
Trichoptera	196	14	77	--
Diptera	85	13	78	--
Chironomidae	1,331	46	38	20
Total	4,164	1,708	1,411	995
July				
Nematoda	--	7	--	--
Oligochaeta	1,110	1,107	149	20
Ephemeroptera	20	4,194	1,031	936
Plecoptera	--	157	32	20
Trichoptera	--	358	142	33
Coleoptera	--	--	--	7
Diptera	14	176	1,325	97
Chironomidae	33	191	115	65
Total	1,177	6,190	2,794	1,178
August				
Nematoda	39	--	--	--
Oligochaeta	671	1,346	26	39
Ephemeroptera	568	4,514	1,565	2,066
Plecoptera	7	864	55	--
Trichoptera	1,262	4,265	1,702	208
Diptera	306	163	78	26
Chironomidae	465	1,621	141	318
Total	3,042	12,773	3,567	2,657

Table 4-17 (Continued)

Station/Taxa	Density (Units/m^2)			
October	1974	1975	1978	1979
Nematoda	119	7	6	--
Oligochaeta	427	371	13	299
Ephemeroptera	1,165	1,802	928	3,515
Plecoptera	226	85	52	117
Trichoptera	1,974	527	273	936
Diptera	200	27	26	46
Chironomidae	303	282	--	812
Total	4,414	3,101	1,298	5,725

[1] Diptera other than Chironomidae

Table 4-18. Comparison of Diversity Indices of Macroinvertebrates During RBOSC MDP Studies (1978 and 1979) and RBOSC Aquatic Baseline Studies (1974-1976)

			Baseline			MDP	
Location	Month	Index	1974	1975	1976	1978	1979
Station 13	April	Shannon	--	2.72	2.36	2.47	2.06
		Evenness	--	.61	.58	.92	.94
		No. of Species	--	22	17	7	9
	June	Shannon	--	1.97	1.60	1.11	.44
		Evenness	--	.93	.57	.67	.31
		No. of Species	--	5	5	3	4
	July	Shannon	--	2.51	3.65	.86	1.02
		Evenness	--	.90	.78	.67	.57
		No. of Species	--	7	25	2	6
	August	Shannon	--	3.37	3.10	1.86	.56
		Evenness	--	.76	.66	.90	.29
		No. of Species	--	21	26	2	6
	October	Shannon	2.79	2.34	--	.96	1.47
		Evenness	.60	.59	--	.35	.64
		No. of Species	24	16	--	8	10
Station 14	April	Shannon	--	2.04	1.81	2.96	1.34
		Evenness	--	.52	.45	.68	.44
		No. of Species	--	15	17	21	19
	June	Shannon	--	2.62	2.42	3.14	1.44
		Evenness	--	.73	.59	.70	.47
		No. of Species	--	12	18	23	22
	July	Shannon	--	1.54	3.44	2.77	1.74
		Evenness	--	.41	.75	.61	.61
		No. of Species	--	14	24	23	17
	August	Shannon	--	2.18	2.39	1.61	1.14
		Evenness	--	.52	.73	.48	.39
		No. of Species	--	18	6	10	18
	October	Shannon	2.33	3.14	--	1.97	1.49
		Evenness	.61	.79	--	.48	.57
		No. of Species	15	16	--	12	14

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979
Station 20	April	Shannon	--	2.74	2.17	2.65	1.66
		Evenness	--	.69	.65	.69	.86
		No. of Species	--	16	10	15	8
	June	Shannon	--	2.81	2.45	2.67	1.59
		Evenness	--	.79	.65	.73	.69
		No. of Species	--	12	14	13	10
	July	Shannon	--	1.74	2.74	3.16	.82
		Evenness	--	.53	.67	.81	.29
		No. of Species	--	10	17	15	16
	August	Shannon	--	2.51	2.19	2.47	1.78
		Evenness	--	.85	.59	.59	.66
		No. of Species	--	8	13	18	15
	October	Shannon	--	2.76	2.47	1.41	1.84
		Evenness	--	.74	.65	.48	.68
		No. of Species	--	14	14	8	15
Station 21	April	Shannon	--	2.42	2.38	2.75	1.64
		Evenness	--	.65	.81	.71	.66
		No. of Species	--	13	8	15	12
	June	Shannon	--	2.97	2.74	2.79	1.37
		Evenness	--	.70	.64	.77	.70
		No. of Species	--	19	19	13	7
	July	Shannon	--	2.65	3.21	3.47	1.26
		Evenness	--	.75	.77	.74	.47
		No. of Species	--	12	18	26	15
	August	Shannon	--	3.03	1.45	2.27	1.91
		Evenness	--	.87	.47	.55	.64
		No. of Species	--	11	9	18	20
	October	Shannon	2.43	2.42	--	1.52	1.82
		Evenness	.71	.62	--	.48	.63
		No. of Species	11	15	--	9	18

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979
Station 27	April	Shannon	--	3.04	2.40	3.35	1.50
		Evenness	--	.79	.57	.69	.65
		No. of Species	--	17	19	20	10
	June	Shannon	--	--	3.28	--	--
		Evenness	--	--	.71	--	--
		No. of Species	--	--	24	--	--
	July	Shannon	--	1.72	2.73	3.15	2.31
		Evenness	--	.97	.66	.86	.72
		No. of Species	--	4	18	9	25
	August	Shannon	--	3.28	3.72	2.93	1.87
		Evenness	--	.78	.81	.72	.57
		No. of Species	--	19	24	17	26
	October	Shannon	3.61	4.04	--	2.48	2.23
		Evenness	.83	.83	--	.73	.70
		No. of Species	20	29	--	10	24
Station 29	April	Shannon	--	3.49	2.94	3.41	1.64
		Evenness	--	.71	.79	.89	.66
		No. of Species	--	30	14	15	12
	June	Shannon	--	0[1/]	2.69	0[1/]	0[1/]
		Evenness	--	--	.6	--	--
		No. of Species	--	--	15	--	--
	July	Shannon	--	1.37	3.47	2.58	1.45
		Evenness	--	.53	.73	.66	.54
		No. of Species	--	7	27	16	15
	August	Shannon	--	3.73	3.67	2.94	1.61
		Evenness	--	.79	.81	.70	.55
		No. of Species	--	26	23	19	19
	October	Shannon	--	3.41	3.58	2.23	2.25
		Evenness	--	.72	.73	.71	.69
		No. of Species	--	27	30	9	26

Table 4-18. (Continued)

Location	Month	Index	Baseline 1974	Baseline 1975	Baseline 1976	MDP 1978	MDP 1979
Station 27	April	Shannon	--	3.04	2.40	3.35	1.50
		Evenness	--	.79	.57	.69	.65
		No. of Species	--	17	19	20	10
	June	Shannon	0[1/]	0[1/]	3.28	0[1/]	0[1/]
		Evenness	--	--	.71	--	--
		No. of Species	--	--	24	--	--
	July	Shannon	--	1.72	2.73	3.15	2.31
		Evenness	--	.97	.66	.86	.72
		No. of Species	--	4	18	9	25
	August	Shannon	--	3.28	3.72	2.93	1.87
		Evenness	--	.78	.81	.72	.57
		No. of Species	--	19	24	17	26
	October	Shannon	3.61	4.04	--	2.48	2.23
		Evenness	.83	.83	--	.73	.70
		No. of Species	20	29	--	10	24
Station 29	April	Shannon	--	3.49	2.94	3.41	1.64
		Evenness	--	.71	.79	.89	.66
		No. of Species	--	30	14	15	12
	June	Shannon	--	0[1/]	2.69	0[1/]	0[1/]
		Evenness	--	--	.6	--	--
		No. of Species	--	--	15	--	--
	July	Shannon	--	1.37	3.47	2.58	1.45
		Evenness	--	.53	.73	.66	.54
		No. of Species	--	7	27	16	15
	August	Shannon	--	3.73	3.67	2.94	1.61
		Evenness	--	.79	.81	.70	.55
		No. of Species	--	26	23	19	19
	October	Shannon	--	3.41	3.58	2.23	2.25
		Evenness	--	.72	.73	.71	.69
		No. of Species	--	27	30	9	26

[1/] No sample due to high water conditions

The density of macroinvertebrates at Station 13 on Corral Gulch is consistently lower than Station 14 and other sites in the study area throughout the 1979 sampling period. Station 13 showed a lower diversity for all months sampled; dominant taxa included Oligochaeta (Tubificidae and Naididae) and Chironomidae except for October when the mayfly Baetis sp and a winter stonefly (Capnidae) were found in abundance.

In 1979, Station 13 had very few species present. During the Baseline Studies (1974-1976), this site generally had a greater number of species and higher diversity as well as greater total densities than during the 1978-1979 monitoring phase. The macroinvertebrate community at this station has undergone a radical change in the numbers of species and in the kinds of taxa collected since the initiation of project activities. In 1974 to 1976, more species of Ephemeroptera, Plecoptera, and Chironomidae were collected. During 1978 and 1979, however, all taxa were reduced in numbers and many were absent. Since mining was implemented after the baseline sampling periods, Station 13 has undergone extreme variation in flow due to discharge from pumping of dewatering wells in spring and early summer. This has caused a scouring of the gravel and sand substrate and the concomitant removal of habitat for many organisms. In addition, discharges have caused a certain amount of siltation to form, filling niches, and further reducing macroinvertebrate habitat availability. Tubificidae, Naididae, and some species of Chironomidae are able to withstand stressful situations and thus, have been able to remain and thrive at Station 13. The increase in numbers of Baetis sp. and the Plecopteran family Capnidae in October, 1979 indicates a slight recovery from 1978 when very few of these organisms were found. In 1978, the flows from pumping were extremely high, which resulted in the reduced fauna.

Macroinvertebrate samples from Station 14 (also on Corral Gulch) were more numerous and more diverse than those of Station 13 during 1979. The annelid families Tubificidae and Naididae were by far the most abundant groups, yet the dipteran families Chironomidae, Muscidae, and Simulidae were also important groups. The Oligochaeta usually accounted for approximately 50% of all organisms throughout the year. Cricotopus, Endochironomus, and Cardiocladius were the most important Chironomidae. Baetis was fairly abundant in July; Ephemerella inermis, Hydropsyche, and Cheumatopsyche were also found, but in very low numbers. Callibaetis,

which was so numerous in the early studies, reappeared in May, 1979, but very few were counted.

There has been considerable habitat alteration at Station 14 over the years included in the study. Originally, this was a pond habitat, receiving flow from seepage and having many macrophytes; high waters, bulldozers, and insertion and removal of two weirs have caused drastic changes. Because of this, year-to-year comparisons for this site are very difficult. Pond-like genera such as Callibaetis or groups such as Dytiscidae and Corixidae had disappeared or had been much reduced in 1976. The habitat is now "pond-like" but much more silted over, with fewer macrophytes. In both 1978 and 1979, the most abundant group was Oligochaeta, a group which thrives in a depositional area such as Station 14 is now.

In 1979, Station 14 generally had lower species diversities for all months as compared to previous years. This may be explained by the tremendous numbers of Oligochaeta. The number of species found has remained relatively constant through the baseline and monitoring programs, yet the composition has changed radically.

The macroinvertebrate fauna at Stations 20 and 21 in Yellow Creek are similar in species composition, density, and diversity. Chironomidae and Simulidae were the most abundant groups in 1979. Cardiocladius, Cricoptopus, and Chironomidae pupae were most numerous. Some Ephemeroptera and Coleoptera were found, as well as some Tubificidae, yet all were few in numbers.

In general, the macroinvertebrate communities of Station 20 and 21 remained fairly consistent from 1974 to 1978, with a slight decrease in density and diversity in 1979. This may have been due to flash floods which occurred late in 1978 and caused substrate scouring and the removal of macroinvertebrates. Station 21 generally had greater numbers of Oligochaeta than Station 20. This may be explained by the fact that Station 21 is slightly wider and deeper and the water is slower moving than at Station 20.

Species diversities at Stations 20 and 21 have been relatively low during all years due to the dominance of a few species. This may be explained by high

dissolved solids concentrations which may limit diversity.

Ephemeroptera was the most important group at Station 27 on the White River above the confluence with Yellow Creek in 1979. Baetis, Ephemerella inermis, Choroterpes, and Tricorythodes were the most abundant mayfly taxa. Other Ephemeroptera included Rhithrogena, Traverella albertana, Heptagenia, and Ephoron album. The tricopterans Hydropsyche and Cheumatopsyche were also abundant. Chironomidae (Cricotopus, Microtendipes, Micropsectra) were found to be numerous especially in October when Oligochaeta was also very numerous.

Station 29, on the White River below the confluence of Yellow Creek, is similar in species composition and total densities to Station 27. Both stations have remained fairly stable throughout the sampling periods from 1974-1979; however, there was a decrease in diversity at both stations in 1979. The reason for this is unknown, but may be explained by natural fluctuations in composition. The White River has a rubble-cobble substrate, yet due to run-off from storms and other activities, silt tends to deposit. This may explain the relatively high numbers of Oligochaeta and Chironomidae found in October when the water was lower. An increase in silt, which fills niches, may explain the lowered diversity. The number of taxa has remained fairly constant from 1974 to 1979 and total densities have not fluctuated greatly over the same period.

In summary, Station 13 on Corral Gulch has been directly affected by project activities. This is reflected in the low diversity, densities, and low number of taxa. The groups Oligochaeta and Chironomidae are the most numerous organisms indicating an unstable site, since these groups are able to withstand the frequent substrate alterations that had been typical of this station. The low numbers of other groups of insecta is also indicative of a community in a stressed state.

Station 14, on Corral Gulch, downstream from Station 13, is difficult to assess. Over the years, natural floods as well as man-caused situations have altered the type of habitat and thus caused changes in the macroinvertebrate community. It would be difficult to say if any mining activity has affected the area. Station 14 can be presently described as a "pond-like" habitat with slow flow and silt being deposited from upstream. It is characterized by high numbers of Oligochaeta and Chironomidae.

The macroinvertebrate communities at Stations 20 and 21 on Yellow Creek have remained fairly stable throughout the baseline and monitoring programs. Any changes in diversity for 1979 may be due to the flash floods that occurred in September, 1978. Stations 20 and 21 can be characterized by a high Chironomidae population with a few other groups from Insecta as well as Oligochaeta. This is not a highly diverse area.

Stations 27 and 29 on the White River have well-balanced, highly diverse macroinvertebrate communities typical of rivers in the semi-arid west. There is little apparent difference between 27, which is upstream from the Yellow Creek outflow, and 29, which is downstream. Both stations are characterized by high numbers of Ephemeroptera (mayflies) and diverse populations of other representatives from Insecta including Trichoptera, Plecoptera, and Diptera. There is a fair number of Oligochaeta at both sites, which is indicative of silt deposits in rivers of semi-arid regions. In general, there appears to be little, if any, changes in the macroinvertebrate communities of Station 27 and 29 due to mining activities on Tract C-a.

4.3 SUMMARY

Physical parameters examined at each of the aquatic sampling stations indicate both seasonal and annual variability. Few trends or major changes in the physical measurements can be detected from the data. Sampling Stations 13 and 14 showed an increase in the volume of flow. This increase is hypothesized to be the result of operational discharge of water into Corral Gulch, which in turn increased the depth, width, and velocity of water at Stations 13 and 14. An increase in conductivity and turbidity was noted at Station 13, presumably as a result of water discharge into Corral Gulch. Physical data collected to date do not lend themselves well to statistical analyses because of the high degree of seasonal and annual variability exhibited by aquatic habitats in the area, and lack of adequate long-term information. Changes or trends in physical data, utilizing such techniques as trend analysis, time series analysis, and cluster analysis, will be studied as soon as adequate data become available.

Water quality measurements made in 1979 indicate no large changes in White River water quality above or below its confluence with Yellow Creek. Examination of the 1979 data and data collected in the Baseline and early monitoring phase, analyzed with standards established by EPA procedures, also shows no detectable differences in water quality or aquatic sampling stations on or near Tract C-a.

The 1979 total mean Periphyton density for all aquatic sampling stations was 2698 units/mm^2. Mean density values ranged from a high at Station 14 (6446 units/mm^2) to a low at Station 29 (411 units/mm^2). Annual variations in periphyton densities are large on a monthly basis, and are directly related to such highly variable environmental parameters as light, temperature, current velocity, spring run-off, turbidity, and substrate type.

Generally, 1979 densities, diversities, and biomass estimates were lower than 1978 and 1977 values. Periphyton were dominated by Achnanthes spp., primarily Achnanthes minutissima, at Station 13 during the baseline period, while Phormidium spp. dominated during the spring and early summer and Achnanthes spp. dominated during the fall of 1979. This change in dominant species may be due to the

increase in turbidity and flow of water at Stations 13 and 14 during the spring. Variations in species dominance is not uncommon in aquatic community structures with a high degree of variability such as increased turbidity and velocity. Change in dominance of one species over another is frequently seen within variable physical environments. When more data are collected, in future years, the question "Are there any significant changes in the correlation between dominance by particular species and associated physical measurements" can be addressed and tested statistically. In summary, changes may have occurred in the periphyton communities since the baseline period that cannot be accounted for by seasonal variations, and further examination over a longer time period is warranted.

Benthos samples collected from Stations 13 and 14 in 1979 indicate a decrease in the number of representative taxa and total numbers of macroinvertebrates, due probably to increased turbidity and water velocity which results in habitat modification, stream erosion, and scouring of the gravel and sand substrate. An increase in Baetis sp. and the Plecopteran family Capmidae was noted in 1979 indicating a slight recovery in the numbers of these organisms from 1978 at Stations 13 and 14. Considerable habitat alteration at Station 14 over the years has resulted in a change in basic species composition from pond-like genera, such as Callibaetis, to a silted pond-like habitat taxa, such as members of the class Oligochaeta. Differences in life history strategies indicate that Callibaetis survive in a solid non-depositional substrate habitat, while the oligochaeta thrive on a silted highly depositional habitat.

The macroinvertebrate communities of Stations 20 and 21 were fairly consistent between 1974 and 1978. A slight decrease in density and diversity was seen in 1979 that may have been caused by the flash flooding experienced in late 1978, which resulted in considerable substrate scouring and removal of macroinvertebrates. Stations 27 and 29 have shown little differences between baseline and MDP monitoring. In general, there appears to be little, if any, changes in the benthos communities of Stations 20, 21, 27, and 29 due to mining activities on Tract C-a.

Statistical analysis of the benthic sampling program is presently limited to relative abundance, density and diversity measurements. The procedures are

limited to annual comparisons and cannot give an overall long term picture of the changes in benthic community structure. Analysis of the benthos community by powerful cluster techniques and nonparametric ranking procedures when a minimum of 6 years data are collected will be appropriate and useful. Use of these procedures for examination of long term changes in the benthos will give a better understanding of the effects of mining and physical and water quality changes on the benthic community.

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SECTION 5
HYDROLOGY STUDIES

This report presents the data, findings, and analysis of the hydrologic monitoring program for Tract C-a, for the period of December 1978 through November 1979. The material presented in this report is divided into three (3) general categories; surface water, groundwater, and development activities monitoring.

The surface water and groundwater monitoring programs have been carried out on a continuing basis since the beginning of the baseline period. The purpose of this monitoring program was to detect regional hydrologic impacts of the oil shale development activities on Tract C-a. Surface water has been collected from springs and seeps and surface water gaging stations in the general area of the development. Groundwater data have been collected from alluvial monitoring holes and from upper aquifer and lower aquifer wells. The map shows the location of these monitoring stations.

The purpose of the development activities monitoring program is to document the quantity and quality of waters which are displaced as a result of the oil shale development activities. These activities include upper aquifer dewatering, injection of upper aquifer water back into the upper aquifer, discharge of upper aquifer water into surface streams, land-disturbing and other miscellaneous activities that would affect hydrology. The monitoring stations for the development activities monitoring program have been installed as needed, and in the immediate proximity of development activities. This monitoring program was formerly designated the "operational" monitoring program.

The material presented on the following pages describes the data which were collected in each of the three (3) monitoring programs, the analyses of these data, and the conclusions which have been drawn from these analyses regarding hydrologic impacts.

Data are collected at surface gaging stations by the United States Geological Survey (U.S.G.S.). Other data are collected as described herein by RBOSC and our subcontractors. Hydrologic data gathered during the reporting period, as well as statistical analyses and other support documentation are presented in Volume 3--Appendices.

5.1 SURFACE WATER

A. Streams

1. Objectives

The objective of the stream monitoring program is to measure and evaluate changes in water quantity and water quality relative to the baseline period.

2. Methods

Surface water quality and quantity are monitored through the use of six surface water gaging stations by the U.S. Geological Survey. The gaging station locations are illustrated on Map 1 (see map pocket). The monitoring gaging stations are shown on Table 5-1. The identification number, tributary drainage area, and annual runoff for each station are shown on Table 5-2. Conductivity, pH, temperature, and flow are monitored on a continuous basis. Quarterly monitoring includes the major ions (Ca, Mg, SO_4, Cl, K, HCO_3, CO_3) and Sodium, Fluoride, Silica, pH, and Alkalinity. Semi-annual analyses are performed for the baseline constituents shown in Table 5-3 at all six surface water gaging stations and surface water impoundments where water is present. In addition to the monitoring done by the U.S.G.S., physical parameters are monitored on a daily basis by Tract personnel for special analyses, because this station is located downstream from the location where dewatering water is discharged to the stream. U.S. G.S. discharge data is included in Appendix 5-1.1 and water quality data is included in Appendix 5-1.2.

3. Results and Discussion

a. Physical parameters - As indicated in Table 5-1, Stations A, Dry Fork, and Station E, "Rinky Dink" Gulch were dry throughout the 1978-1979 reporting period. Stations C, Box Elder Gulch near the west tract

Table 5-1 . U.S. Geological Survey Surface Gaging Stations

U.S.G.S. I.D. No.	Tract Station	Description
09306237	A	Dry Fork near West Tract Boundary-dry during reporting period
09306235	B	Corral Gulch near West Tract Boundary
09306240	C	Box Elder Gulch near West Tract Boundary-dry November 1978 through March 1979
09306242	D	Corral Gulch near East Tract Boundary
09306241	E	Box Elder Tributary near East Tract Boundary "Rinky Dink Gulch"-dry during reporting period
09306255	F	Yellow Creek near White River

Table 5-2. U.S.G.S. Gaging Stations, Drainage Areas, and Annual Runoff in Acre-Feet

Station	Drainage Area(sq.mi)	Water Year 1975	Water Year 1976	Water Year 1977	Water Year 1978	Water Year 1979
A-Dry Fork near west line Tract C-a	2.91	0.2	4.3	11.4	Dry	0.2
B-Corral Gulch near west line Tract C-a	8.44	96.7	98.5	30.8	107.1	225.4
C-Box Elder Gulch near west line Tract C-a	10.29	182.8	34.8	13.9	228.4	256.9
D-Corral Gulch near east line Tract C-1	29.59	626.2	418.1	262.8	1399	2381.7
E-Box Elder tributary east Tract C-1	2.25	0.6	2.3	0.8	Dry	Dry
F-Yellow Creek near White River	262.00	1158.7	1103.1	925.7	1044.6	1020.8

Table 5-3 Water Chemistry Parameters Analyzed Semi-Annually at the Surface Water Gaging Stations and Impoundments During RBOSC MDP Activities

Standard Wet Chemical Analysis[1]

Bromide
Alkalinity
Biological Oxygen Demand
Dissolved Organic Carbon
Boron
Selenium
Calcium
Conductance
Fluoride
Magnesium

Potassium
Silica
Sodium
Chemical Oxygen Demand
Fecal Coliform
Pesticides
Nitrogen, Ammonia
Total Coliform
Strontium
Cyanide

MBAS
Oil & Grease
Sulfate
Ammonia
Bicarbonate
Carbonate
Chloride
Color
Hardness
Dissolved Solids
Suspended Solids
Kjeldahl Nitrogen
Nitrate Plus Nitrite
Odor
Dissolved Phosphate
Turbidity
Dissolved Oxygen
Phenols
Sulfide
pH
Temperature

Radioactivity

Gross Alpha
if 4 pci/l
then Ra^{226}
Natural Uranium

Gross Beta
if 100 pci/l
Then Sr^{90}
Ce^{137}

Silver
Ortho Phosphate
Tin
Aluminum
Arsenic
Cadmium
Chromium
Selenium
Mercury
Zinc
Iron
Lead

Spectrographic Analysis

Molybdenum
Lithium
Manganese
Barium
Beryllium
Germanium
Gallium
Nickel
Titanium
Vanadium
Zirconium
Copper

[1]To EPA or detectable limits already established

boundary, was also dry during the winter months from November 1978 through March 1979. Table 5-1 also shows the months which physical and water quality samples were taken.

Stream flows at the six U.S.G.S. gaging stations are plotted on a monthly basis for the 1979 water year, and for the previous four water years (see Figures 5-1 through 5-3). Natural flows for the 1979 water year were somewhat similar to natural flows in 1975 and 1978. A relatively high flow was recorded at Box Elder Gulch during May of 1979; this can be attributed principally to a higher than average snowmelt for this year. In contrast to previous years, flows at Corral Gulch near the east line of Tract C-a and at Yellow Creek near the White River are much higher than in previous years. This can be attributed to 1) precipitation at Tract C-a, and 2) the discharge of dewatering water into Corral Gulch, which flows into Yellow Creek. The effects of these inflows are much more pronounced and immediate at the Corral Gulch gaging station near the east line of Tract C-a. The discharge flow ceased in Yellow Creek way above the Yellow Creek gaging station. The annual runoff at Corral Gulch increased from a maximum of 626.2 acre-feet during the baseline period to 2,381.7 acre-feet for the 1979 water year.

Figure 5-4 illustrates the overall water balance for Tract C-a. This is a diagram of net outflow from the Tract, and is calculated by subtracting the three surface inflows at Stations A, B, and C from the outflow from the Tract recorded at Station D. During drought conditions in early 1974, there was a negative net outflow from the Tract; inflows exceeded outflows, due to recharge of dry alluvium from lack of precipitation and high evapotranspiration. From 1974 through mid-1978, the net outflow was approximately 25 acre-feet per year. Beginning in late 1978 through the present time, net outflows have markedly increased, indicating the effects of 1) increased precipitation on the Tract for this year, and 2) discharge of dewatering water. The mean net outflow from the Tract for this time period was approximately 150 acre-feet. The high variability in net outflow for

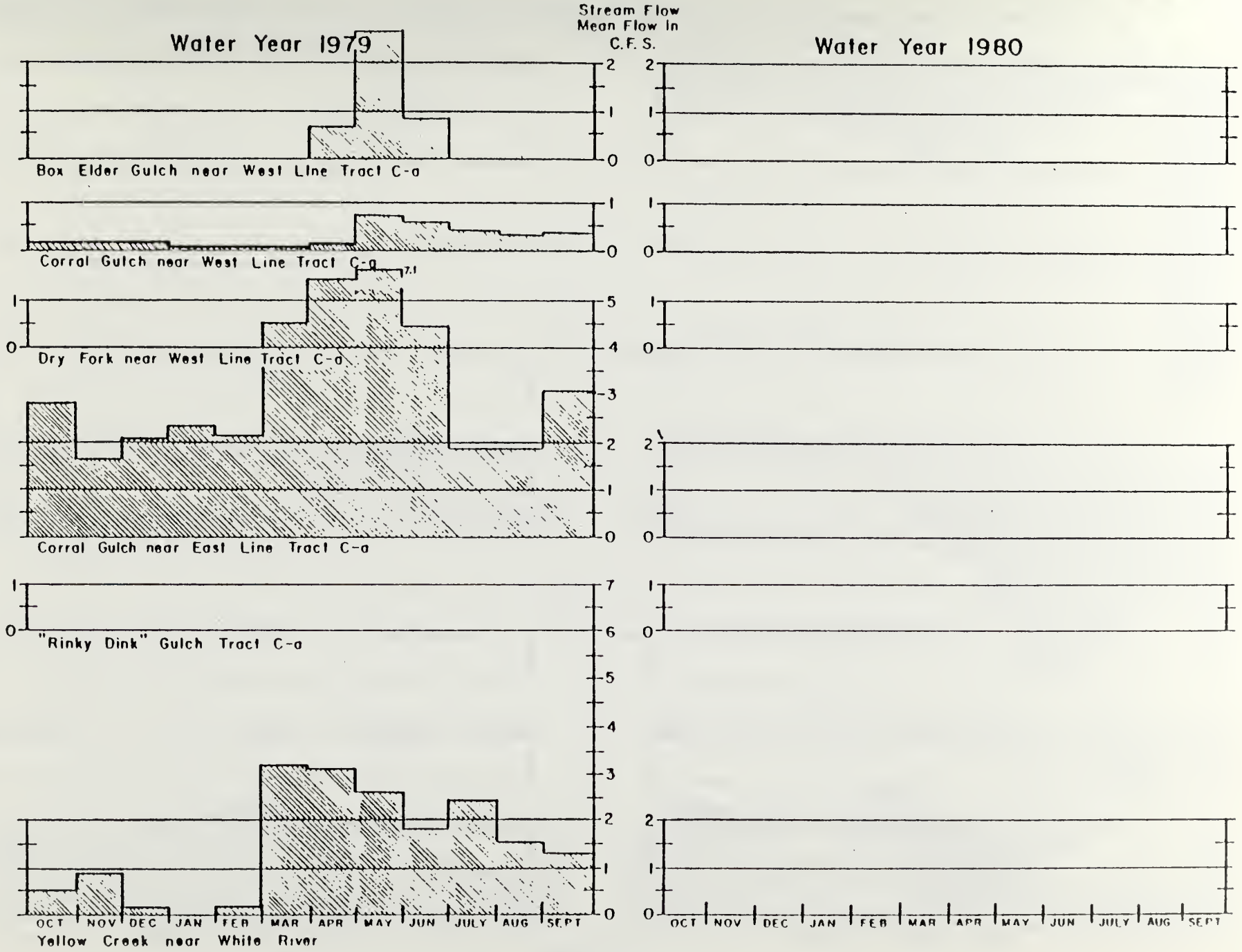


Figure 5-1. Stream Flows at U.S.G.S. Gaging Stations for the 1979 Water Year, Tract C-a

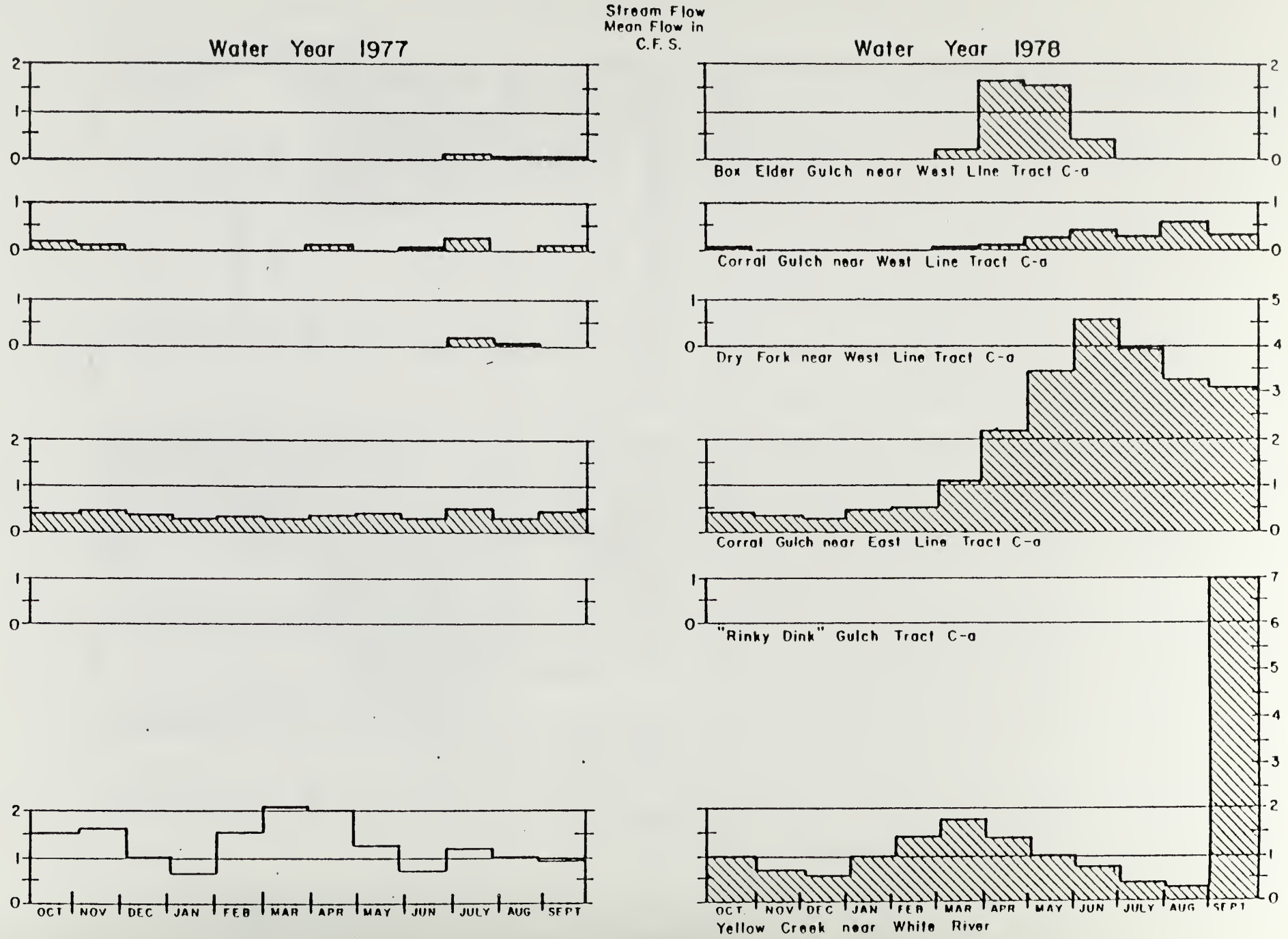

Stream Flow
Mean Flow in
C.F.S.
Water Year 1977
Water Year 1978
Box Elder Gulch near West Line Tract C-a
Corral Gulch near West Line Tract C-a
Dry Fork near West Line Tract C-a
Corral Gulch near East Line Tract C-a
"Rinky Dink" Gulch Tract C-a
Yellow Creek near White River
OCT NOV DEC JAN FEB MAR APR MAY JUN JULY AUG SEPT

Figure 5-2. Stream Flows at U.S.G.S. Gaging Stations for the 1977 and 1978 Water Years, Tract C-a

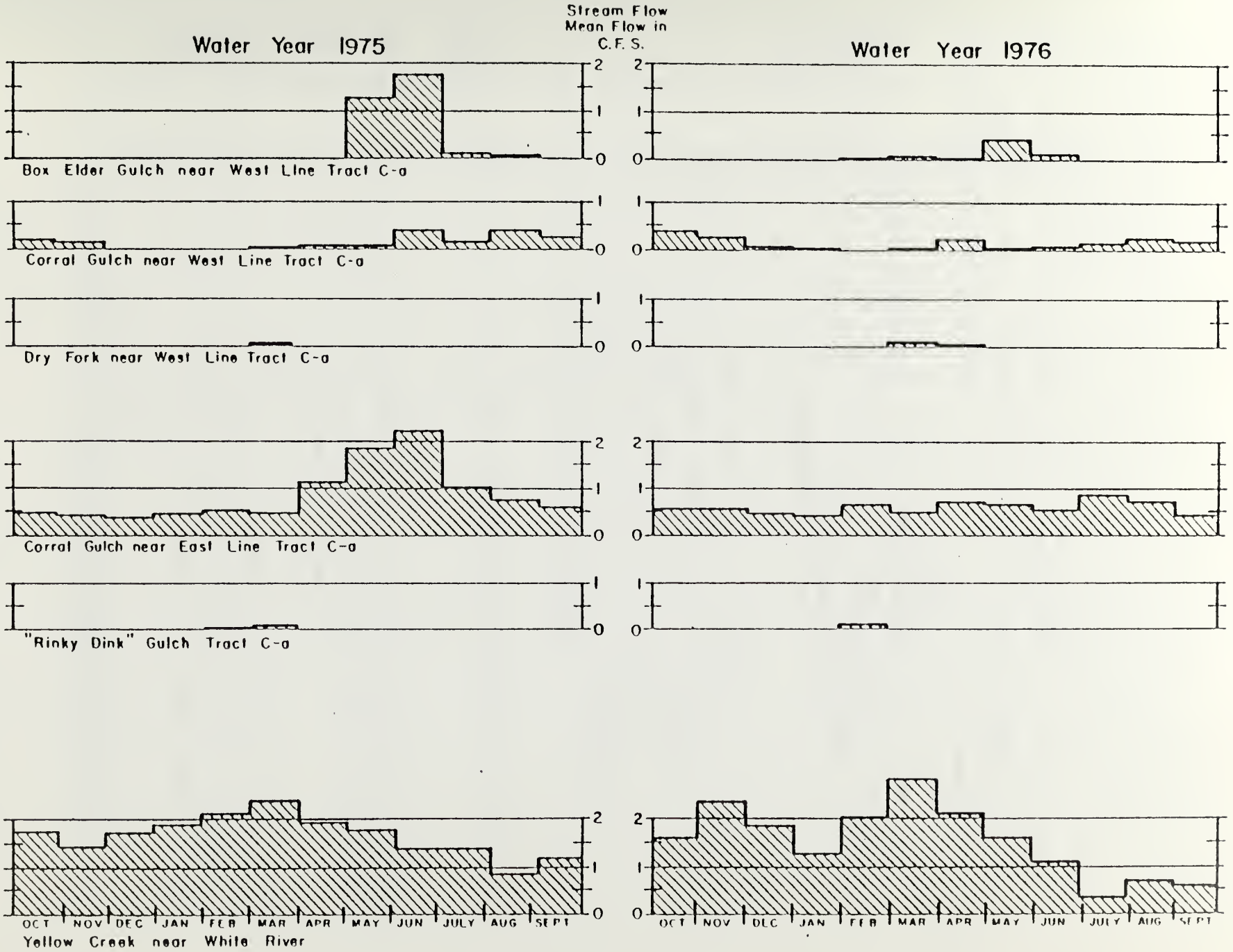


Figure 5-3. Stream Flows at U.S.G.S. Gaging Stations for the 1975 and 1976 Water Years, Tract C-a

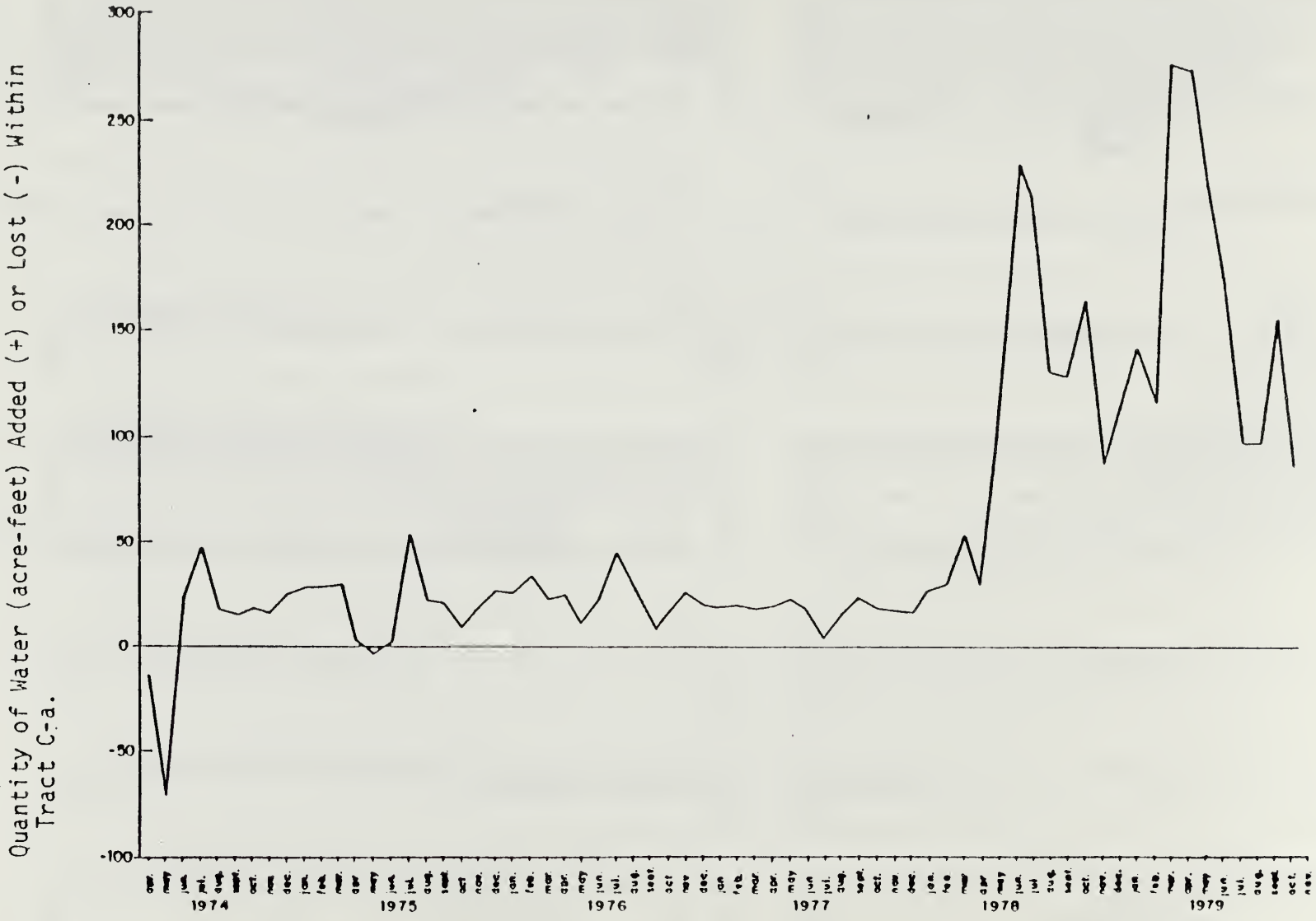


Figure 5-4. Difference Between Surface Water Outflow and Inflows on Tract C-a

the dewatering period may be attributed to several factors. Recharge of the alluvium of Corral Gulch and Yellow Creek has a considerable effect on the amount of flow present in the stream, because recharge reduces stream flow. Surface flows therefore are very sensitive to 1) discharge rate, 2) recharge of low water tables in the stream alluvium, and 3) precipitation and evaporation rates at the site. The maximum ouflow was recorded in March 1979 and was approximately 280 acre-feet.

b. Chemical parameters - Water quality data provided by the U.S. Geological Survey for the reporting period, December 1978 through November 1979 are presented in Appendix 5-1.1 and 5-1.2. Data stations included in the environmental monitoring program are as follows:

- A-Dry Fork near west line Tract C-a (09306237)
- B-Corral Gulch near west line Tract C-a (09306235)
- C-Box Elder Gulch near west line Tract C-a (09306240)
- D-Corral Gulch near east line Tract C-a (09306242)
- E-Rinky Dink Gulch near east line Tract C-a (09306241)
- F-Yellow Creek near White River (09306255)

Stations A and F were dry during the reporting period and thus no data were reported.

Summary statistics for stream water quality stations for the reporting period are reported in Appendix 5-1.3. Results of statistical comparison of reporting period and baseline data are listed in Appendix 5-1.4.

The major purpose of the data evaluation presented in this report is to provide a measure of comparison between the reporting period data and baseline data. Three approaches were used for the comparison of water quality data:

- Identification of cases where maximum concentrations observed for the report period exceeded baseline maximum levels.

- Statistical testing of differences between mean concentrations for the baseline and report periods.
- Evaluation of changes in general water quality composition between baseline and reporting periods.

These approaches were applied to water quality data for streams, alluvial aquifers and deep (upper and lower) aquifers.

Comparison of observed maximum concentrations from the baseline and reporting period is used to provide an initial measure of the extent to which reporting period observations are within the range of baseline observations. When baseline maxima are exceeded by report period data, examination of the relative magnitude of the difference provides a basis for inferring the cause and potential impacts of the higher observations.

Students t, F and t' tests were used to compare baseline and report period mean concentrations for individual chemical constituents. Means of data from either individual sampling stations or groups of stations from the report period were compared to baseline data means. The Student's t test was used to test the null hypothesis ($\alpha = 0.05$): there is no significant difference between the means of baseline and MDP data. Comparison of a computed t value with tabular values indicates whether the null hypothesis is accepted or rejected. If the Student's t value is greater than the tabulated value then the null hypothesis of equality of means is rejected.

One of the basic assumptions of the t test is that the variances of the two populations being compared are equal. F values were used to test the null hypothesis ($\alpha = 0.05$): there is no significant difference between the variances of baseline and MDP data. As with the t test, a computed F value is compared to a tabular value to accept or reject the null hypothesis. If the F test null hypothesis is accepted, then the results of the t test were used to evaluate significant differences between means of the data sets compared.

If the F test null hypothesis is rejected, the t' test was used to compare means. The computed t' value is compared to the tabular value estimated for the regular t test. If the t value is greater than the estimated t' value then the null hypothesis of equality is rejected.

To provide an evaluation of changes in general water quality, Spearman's rank correlation was used to examine a set of water quality consitutents rather than constituents individually. For this analysis, the major inorganic ions (Sodium, Calcium, Magnesium, Potassium, Chloride, Carbonate, Bicarbonate, and Sulfate) were selected for testing and their relative concentrations (in milliequivalents per liter) were used to identify the relative "water quality composition". For the Spearman correlation analysis, the chemical constituents for each data set being compared are ranked relative to concentration. The ordering of the two data sets (one for the baseline and one for the reporting period) is then compared by estimation of the Spearman rank-order correlation coefficient. If this coefficient is close to unity, the two data sets are highly correlated and it is inferred that the general water quality compsosition of the baseline and reporting periods is not different.

As outlined above, the evaluation of stream water quality data for the report period includes indentification of constituents exceeding maximum baseline concentrations. Statistical testing of differences in means of baseline and reporting period data sets and comparison of baseline and reporting period stream water quality composition are presented in Tables 5-4 through 5-10.

Data presented in Table 5-4 show that at each of the stream stations several constituents exceeded baseline maximum observed concentrations. For most of the constituents, interpretation of these data is complicated by single observations during the reporting period. Most of the multiple sample cases listed in Table 5-4 show relatively small increases over the baseline maximum levels. The exceptions are the fluoride and phenol concentration at

Table 5-4. U.S.G.S. Stream Gaging Stations Water Quality Constituents for Which the Maximum Observed Concentration for the Report Period Exceeded the Maximum for the Baseline Period.

Station	Constituent	Maximum Concentration Observed	
		Baseline Period	Report Period
B-Corral Gulch near West Line	D.O. (mg/l)	11.	12.6
	Fluoride (mg/l)	1.5	2.1
	Phenols (ug/l)	3.0	9.0*
C-Box Elder Gulch near West Line	Calcium (mg/l)	86	91
	COD (mg/l)	100	150*
	Carb, org, sus.(mg/l)	2.4	43*
	Strontium (ug/l)	1000	1300*
D-Corral Gulch east of Tract	Ammonia(NH_4)(mg/l)	0.35	0.36*
	Tot. Hard.(Ca,Mg,)(mg/l)	520	530
	Lithium (ug/l)	40	60*
	Magnesium (mg/l)	71	79
	Nitrite (NO_2)(mg/l)	0.10	0.16*
	Nitrogen, Ammonia(mg/l)	0.27	0.28
	Org.Carb,Total(mg/l)	15	18*
	Radium 226 (pc/l)	0.10	0.13*
	Silica (mg/l)	24	27
	Strontium (ug/l)	2000	5000*
	Sulfate (mg/l)	360	400
F-Yellow Creek near White River	Chloride (mg/l)	200	220
	Conductivity,spec(umhos)	5000	5200
	Potassium (mg/l)	7.4	8.6
	Sodium (mg/l)	940	1200
	S.A.R.	19	22
	Temperature (°C)	28.0	29.5

* Single observation for reporting period.

A was dry

B was dry

Table 5-5. Results of testing of equality of baseline and report period stream water quality means. Constituents listed are those for which null hypothesis of equality of means was rejected

Constituent	Stream Station			
	Corral Gulch Near West Line	Box Elder Gulch Near West Line	Corral Gulch Near East Line	Yellow Creek Near White River
Sp. Conductance	(R.P. $\gtrless$ B.L.)[2]	[1]	(R.P. $\gtrless$ B.L.)[2]	[1]
Temperature	<	[3]		
Dissolved Oxygen	>			
Sodium	<		>	
Calcium			<	
Magnesium			>	
Potassium	<		<	
Chloride	<			
Sulfate	<		>	
Fluoride			>	
Silica			>	
SAR	<		>	
Ortho-P			<[4]	
Dis.Ortho-P			<[4]	
Total P			>	
Ammonia			>	

[1] Null hypothesis of equality of means accepted for all constituents tested.

[2] < and > symbols indicate test results showing statistically significant difference in means of baseline and report period; < indicates that report period mean is less than baseline; > indicates report period mean is greater than baseline.

[3] Blank in table indicates that means tested were not significantly different; for constituents not listed, and null hypothesis was accepted.

[4] Report period data provided by USGS were zeros; interpretation of this analytical result is unclear.

Table 5-6. Spearman Rank-Order Correlation Analysis of Baseline and Report Period Means of Major Inorganic Ions, Corral Gulch near west line Tract C-a

Constituent	Baseline Period Mean (mg/l)	Baseline Period Mean (meq/l)*	Baseline Period Rank	Report Period Mean (mg/l)	Report Period Mean (meq/l)*	Report Period Rank
Sodium	84.9	3.69	5	78.8	3.43	5
Calcium	87.8	4.39	4	81.5	4.08	4
Magnesium	58.6	4.80	3	56.8	4.66	3
Potassium	1.4	0.04	7	1.1	0.03	7
Chloride	7.6	0.21	6	6.9	0.19	6
Carbonate	0	0	8	0	0	8
Bicarbonate	387.6	6.35	1	390.0	6.39	1
Sulfate	282.9	5.89	2	266.5	5.55	2

Spearman's Coefficient (r_s) = 1.00

$\sum d = 0$: $\sum d^2 = 0$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

Table 5-7. Spearman Rank-Order Correlation Analysis of Baseline and Report Period Means of Major Inorganic Ions, Box Elder near West Line Tract C-a

Constituent	Baseline Period Mean (mg/l)	Baseline Period Mean (meq/l)*	Baseline Period Rank	Report Period Mean (mg/l)	Report Period Mean (meq/l)*	Report Period Rank
Sodium	42.9	1.87	4	55.9	2.43	4
Calcium	66.4	3.32	1	68.3	3.42	3
Magnesium	39.4	3.23	2	47.6	3.90	1
Potassium	1.2	0.03	6	0.9	0.02	6
Chloride	5.6	1.58	5	5.9	0.17	5
Carbonate	0	0	7	0	0	7
Bicarbonate	338.8	----	-	---	----	-
Sulfate	125.6	2.62	3	182.9	3.81	2

Spearman's Coefficient (r_s) = 0.89

$\sum d = 0$: $\sum d^2 = 6$: $n = 7$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

Table 5-8. Spearman Rank-Order Correlation Analysis of Baseline and Report Period Means of Major Inorganic Ions, Corral Gulch East Side of Tract C-a

Constituent	Baseline Period Mean (mg/l)	Baseline Period Mean (meq/l)*	Baseline Period Rank	Report Period Mean (mg/l)	Report Period Mean (meq/l)*	Report Period Rank
Sodium	109.2	4.75	4	147.4	6.41	3
Calcium	85.6	4.28	5	59.7	2.99	5
Magnesium	62.0	5.08	3	71.2	5.84	4
Potassium	1.6	0.04	7	1.0	0.03	7
Chloride	9.8	0.28	6	10.7	0.30	6
Carbonate	0	0	8	0	0	8
Bicarbonate	492.0	8.07	1	524.4	8.60	1
Sulfate	288.8	6.02	2	338.8	7.06	2

Spearman's Coefficient (r_s) = 0.98

$\sum d = 0$: $\sum d^2 = 2$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

Table 5-9. Spearman Rank-Order Correlation Analysis of Baseline and Report Period Means of Major Inorganic Ions, Yellow Creek Near White River, Tract C-a

Constituent	Baseline Period Mean (mg/l)	Baseline Period Mean (meq/l)*	Baseline Period Rank	Report Period Mean (mg/l)	Report Period Mean (meq/l)*	Report Period Rank
Sodium	778.3	33.8	1	799.4	34.8	1
Calcium	31.8	1.59	7	26.5	1.33	6
Magnesium	108.2	8.87	4	89.2	7.31	4
Potassium	4.1	0.10	8	5.1	0.13	7
Chloride	125.9	3.55	5	127.2	5.58	5
Carbonate	49.6	1.65	6	0 [1)]	0	8
Bicarbonate	1513.9	24.82	2	1866.6 [2)]	30.60	2
Sulfate	556.1	11.59	3	401.2	8.36	3

Spearman's Coefficient (r_s) = 0.93

$\sum d = 0$: $\sum d^2 = 6$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

1) Assumed 0

2) Estimated from alkalinity mean of 1530 mg/l as $CaCO_3$ = 1866.6

Station B; the suspended organic carbon and COD at Station C; and the lithium, nitrite and strontium at Station D were single observations. The fluoride observation of 2.1 mg/l at Station B is the only observation over 0.3 mg/l during the reporting period and hence, does not appear to indicate a change in water quality at that site. During the reporting period, several observations at Station F exceeded the baseline maximum sodium concentration.

Statistical comparison (t, F and t' tests) of baseline and reporting period water quality is summarized in Table 5-5 (Appendix 5-1.4). The null hypothesis of equality of means was accepted for all constituents tested for the Box Elder Gulch and Yellow Creek data stations. Test results inferred significant differences in the means of several constituents monitored at the two Corral Gulch data stations. Where significant change was observed at Corral Gulch near the west line of Tract C-a, mean concentration for the reporting period (except for dissolved oxygen) were lower than means observed during the baseline studies. Corral Gulch near the east line of Tract C-a showed significant increases in levels of specific conductance and several major inorganic ions (sodium, magnesium, and sulfate) during the reporting period. This may reflect surface discharges from the dewatering program.

The high Spearman rank-order correlation coefficients shown in Tables 5-6 through 5-9 indicate that the relative levels of major inorganic ions observed during the reporting period were not significantly different from the baseline period.

c. Special analysis of Corral Gulch East - A detailed analysis was conducted on the behavior of flows and chemical characteristics of the Corral Gulch East gaging station (D) because of the strategic location of this station immediately downstream from the discharge point for mine dewatering water. Flow and various chemical constituents were examined in several combinations as a means of determining the cause and effect relationships between the discharge of dewatering water and flow and quality in the stream.

Average monthly values of conductivity and flow were plotted a a function of time from October 1975 to the present (Appendix 5-1.5). There are two distinct periods illustrated by the data: pre-discharge and post-discharge. Pre-discharge relationships between flow and water quality are seasonal, but the post-discharge water quality is dominated by the quality of the discharge. During the pre-discharge period conductivity averaged 1250 umhos. In the spring, a sharp increase in conductivity was followed by a gradual decrease to below average values in the winter.

The graph of conductivity versus flow (Appendix 5-1.5) for the pre-discharge period shows a dilution with increased flow except for sporadic, high values of conductivity at flows over 0.5 cfs. Below 0.5 cfs the average conductivity was 1240 umhos; between 0.5 and 1.0 cfs it was 1170 umhos and between 1.0 and 2.0 cfs it was 1110 umhos. (sporadic high values discounted).

Graphs of bicarbonate and sodium versus conductivity (Appendix 5-1.5) show correlation coefficients of 0.84 and 0.82 respectively. This behavior indicates the "flushing" of chemical deposits in the upper banks of the stream during times of high runoff. These bank deposits which are mostly sodium bicarbonate, are precipitated in the soil above normal stream level during dry periods when evapotranspiration is high. Spring runoff tends to redissolve these chemical constituents and reintroduce them to the stream which results in high conductivity values.

The graph of conductivity versus flow (Appendix 5-1.5) for the post-discharge periods shows a constant average conductivity value of 1400 umhos which is independent of flow. This value corresponds to the average conductivity of the water discharged from the mine area.

Sediment samples were collected at Corral Gulch East in October and are described in Appendix 5-1.5. Discharge data is also included in Appendix 5-1.5.

B. Springs and Seeps

1. Objectives

The objective of monitoring and observing major springs and seeps is to measure and evaluate changes in the physical parameters (flow, conductivity, temperature, and pH) relative to the baseline period.

2. Methods

Six springs and seeps were monitored during 1979 and are described in Table 5-10.* Specific conductance is measured by the use of a conductivity meter. Flowing water is measured by using a weir, a flume, or integrating cross-sectional velocities. These measurements are made quarterly. The rationale for measuring flows of springs and seeps is based upon analysis of two years of baseline data, which indicated that the four springs and seeps nearest the Tract are hydrologically connected to the upper oil shale aquifer. The two furthest from the Tract are hydrologically connected to the alluvium.

Variations in the water quality of the springs and seeps are detected by analyses of conductivity data. The rationale for using conductivity as a detector parameter is based on high correlation with changes in other water quality parameters as determined during the statistical analysis of data collected during the baseline monitoring. At each of six springs and seeps, conductivity measurements were made six times a year during baseline.

*Two other springs are included in Development Activities Monitoring.

Table 5-10. Spring and Seep Sampling Stations

Station	Name	Drainage
#1	Cathedral Bluffs	Box Elder Gulch southwest of Tract
#2	Spruce Gulch	Box Elder Gulch southwest of Tract
#3	Maverick Spring	Corral Gulch west of Tract
#5	Stake Springs Draw	Southeast of Tract
#8	Box Elder Gulch	On-Tract
#14	84-Ranch	Corral Gulch east of Tract

3. Results and Discussion

All the springs are inaccessible during January, due to snowpack, and Site No. 1, Cathedral Bluffs Spring, remained inaccessible in April. Springs No. 8, Box Elder Gulch, and 14, 84 Ranch, were obscured by surface water run-off, and were not sampled. During July, a complete set of data was taken on flow, physical and chemical parameters, at No. 1, Cathedral Bluffs, No. 2, Spruce Gulch, and No. 3, Maverick Spring. Physical and chemical parameters were measured in July at No. 5, Stake Springs Draw and No. 14, 84 Ranch. Spring No. 8, Box Elder Gulch was dry during July. Locations of these six springs and seep sampling sites are shown on Map 1 (see Map pocket).

Chemical analysis of samples collected on the five spring and seep monitoring stations where flow was present during July 1979 are shown on Table 5-11. With only one full set of chmical data, it was not possible to conduct a statistical analysis of the data. A comparison of the ratios of various constituents in each sample indicates a striking similarity among the five water samples, indicating that these springs and seeps probably have a common source of water. Among the five samples, values for a particular constituent are of similar magnitude, with the exception of the sample at Station 14, for which values are consistently high with few exceptions. The higher concentration at Station 14 is attributed to the longer time the water was underground in contact with dissolvable solids.

A comparison of spring and seep physical data for baseline and reporting period is shown on Table 5-12. Again, because of the small number of data points taken during the reporting period, it was not possible to conduct a statistical analysis of possible significant difference between baseline and reporting periods. In general, it is observed that conductivities have increased slightly, and that temperature may be about the same.

Table 5-11. Chemical Analysis of Springs and Seeps, July 28, 1979

Constituent (mg/l)	Spring #1	#2	#3	#5	#8	#14
Ammonia N	.1	<.1	<.1	<.1		.4
Bicarbonate	439	451	421	535		812
Calcium	48	52	54	56		56
Carbonate	<.1	<.1	12	<.1		<.1
Fluoride	.3	.3	.2	.3		.4
Iron	<.05	<.05	<.05	<.05		<.05
Magnesium	58	49	58	81		157
Nitrate-Nitrite	1.8	.5	.4	2.3		<.1
Phosphate	<.1	<.1	<.1	<.1	D	<.1
Potassium	1.0	.1	1.7	23	R	7.0
Silicon Dioxide	24	20	16	12	Y	27
Sodium	60	75	129	94		220
Sulfate	120	130	280	240		530
Total Hardness	356	332	372	472		784
Alkalinity	359	369	354	438		664
Suspended Solids	2.0	2	1.0	1.0		1.0
Color (units)	6.0	5.0	3.0	58		80
Odor	good	good	good	earthy		earthy
Temperature(C^{o})	7.5	9.0	7.5	10.0		12.0
Chloride	5.6	6.9	10	9.0		21

Table 5-12. Comparison of Spring and Seep Physical Data, Baseline and Reporting Periods, Tract C-a

Baseline Period

Spring & Seep	Flow(gpm)	Temp (C^o) Max	Temp (C^o) Min	Conductivity (umhos/cm) Max	Conductivity (umhos/cm) Min	pH* Max	pH* Min
#1	22	19	1	950	825		
2	346	11	7	1200	1000		
3	3	21	5	1350	850		
5	227	22	3	1500	1300		
8	81	12	5	1100	850		
14	18	19	8	2000	1550		

Report Period-April, July, October, 1979

Spring & Seep	Flow (gpm) 4-26	7-28	10-15	Temp (^oC) 4-26	7-28	10-15	Conductivity (umhos/cm) 4-26	7-28	10-15	pH 4-26	7-28	10-15
#1	I	20	1	I	7.5	8.3	I	800	850	I	7.1	7.5
2	255	26	0.1	8.5	9.0	8.9	1120	850	800.	7.0	7.0	7.7
3	0.7	1.9	49	9.5	7.5	13.9	1300	1000	950	7.0	7.2	9.2
5	---	---	75	6.0	10.0	11.1	1280	1600	1450	7.0	7.3	8.0
8	C	D	130	C	D	7.8	C	D	850	C	D	7.7
14	C	---	2	7.5	12.0	6.7	2700	2000	2300	7.8	7.7	8.0

I = Inaccessible

C = Submerged under runoff water

D = Dry

* = Data inaccessible

C. Erosion Stations

1. Objectives

The objective of the erosion station monitoring program is to measure and evaulate changes in stream morphology during the modular development phase, and to identify, if possible, the cause of these changes.

2. Methods

Each erosion station is monitored twice monthly. At each station, a stake is located on either side of the channel and measurements of elevation are taken every six inches on a straight line between the two stakes measuring from the left bank looking downstream. The locations of these erosion monitoring stations are shown on Map 1, Map pocket.

3. Results and Discussion

Channel cross-sections for each of the 10 erosion sedimentation stations are shown on Figures 5-5 through 5-14. On each plot, only four cross-sections representing four days spaced throughout the year are shown, rather than all cross-sections which were measured. It would not be possible to superimpose all the data collected on one graph for each cross-section; therefore four representative cross-sections were selected from the data and plotted, to indicate any changes in channel morphology during the year. In most cases, the four representative cross-sections selected were three months apart. Station 1A remained stable; Station 3 widened from 2 to 7 feet and filled in a foot of the bottom; Station 4 filled two feet; Station 5 remained stable; Station 6 remained stable; Station 7 deepened two feet; Station 8 remained stable; Station 9 remained stable; Station 10 may have filled in 0.5 foot; and Station 11 remained stable.

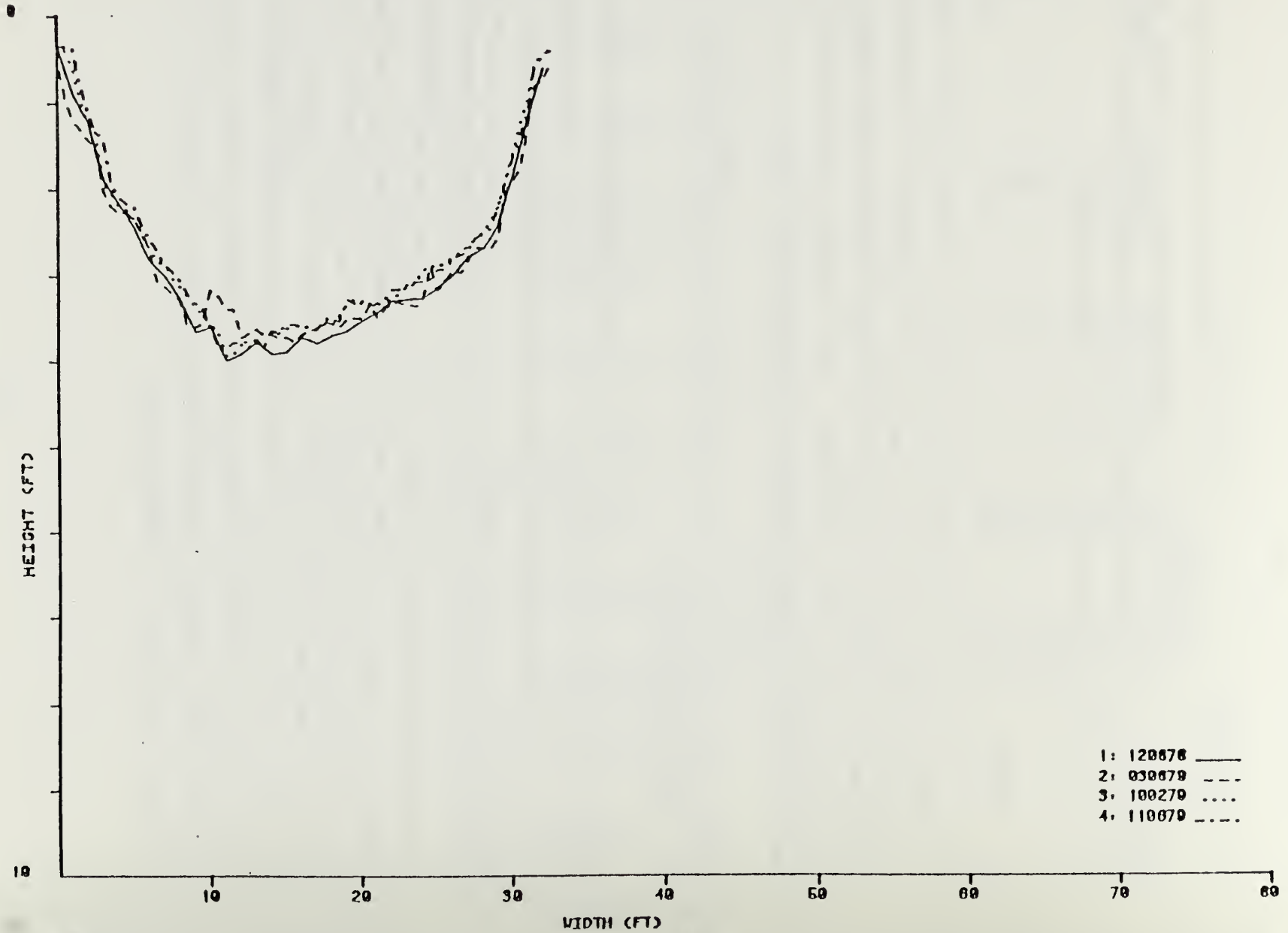


Figure 5- 5. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

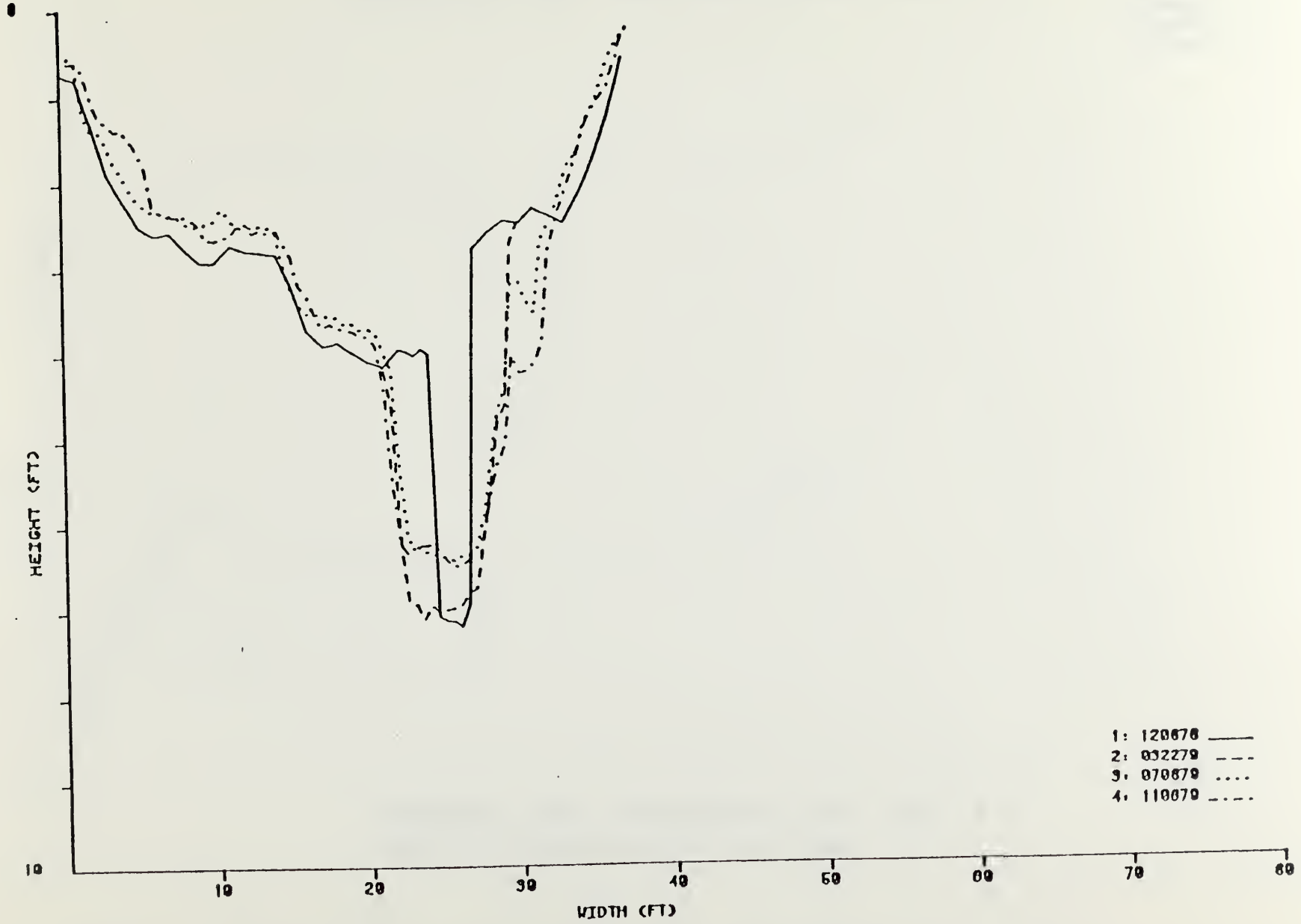


Figure 5- 6. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

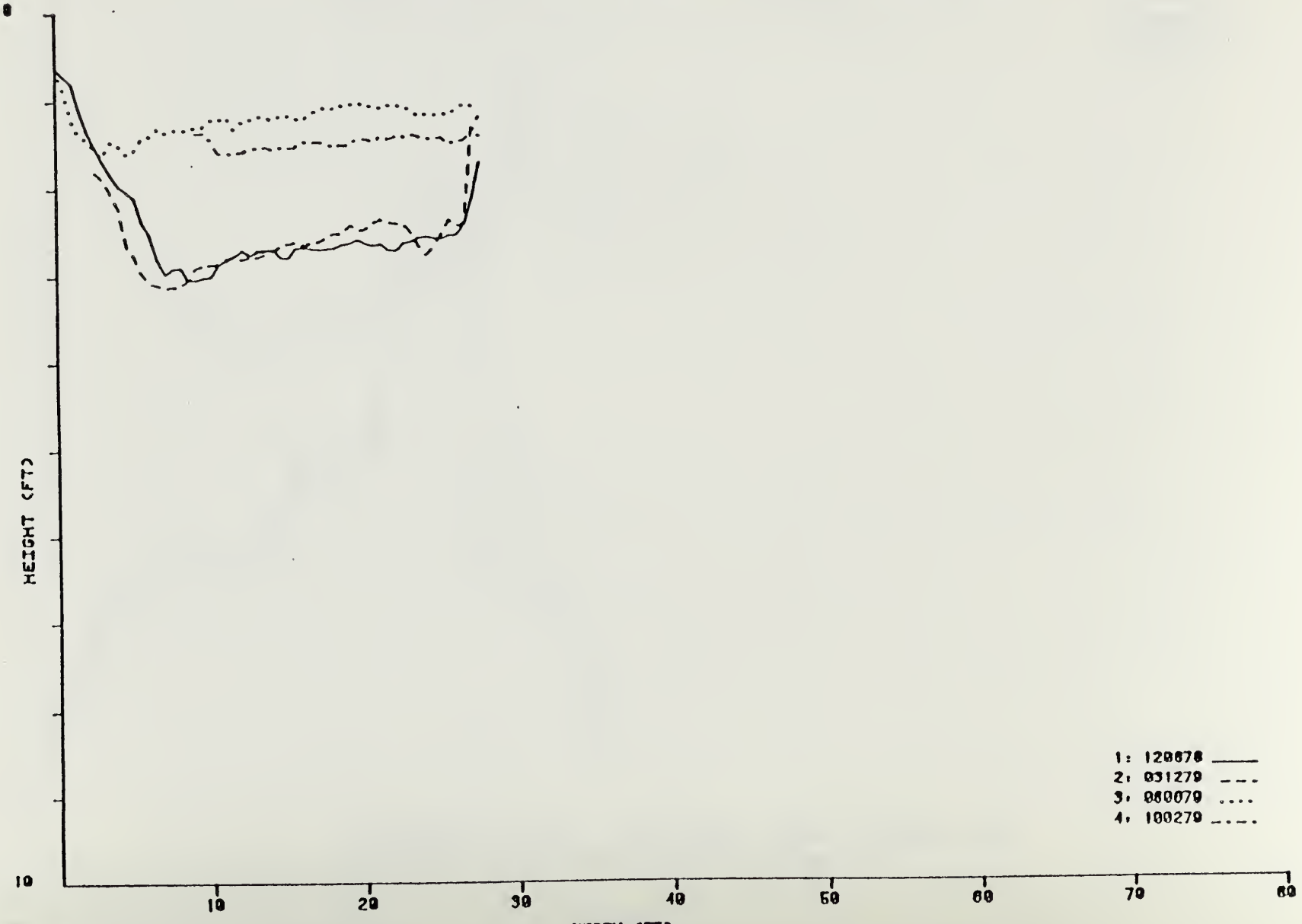


Figure 5-7 . Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

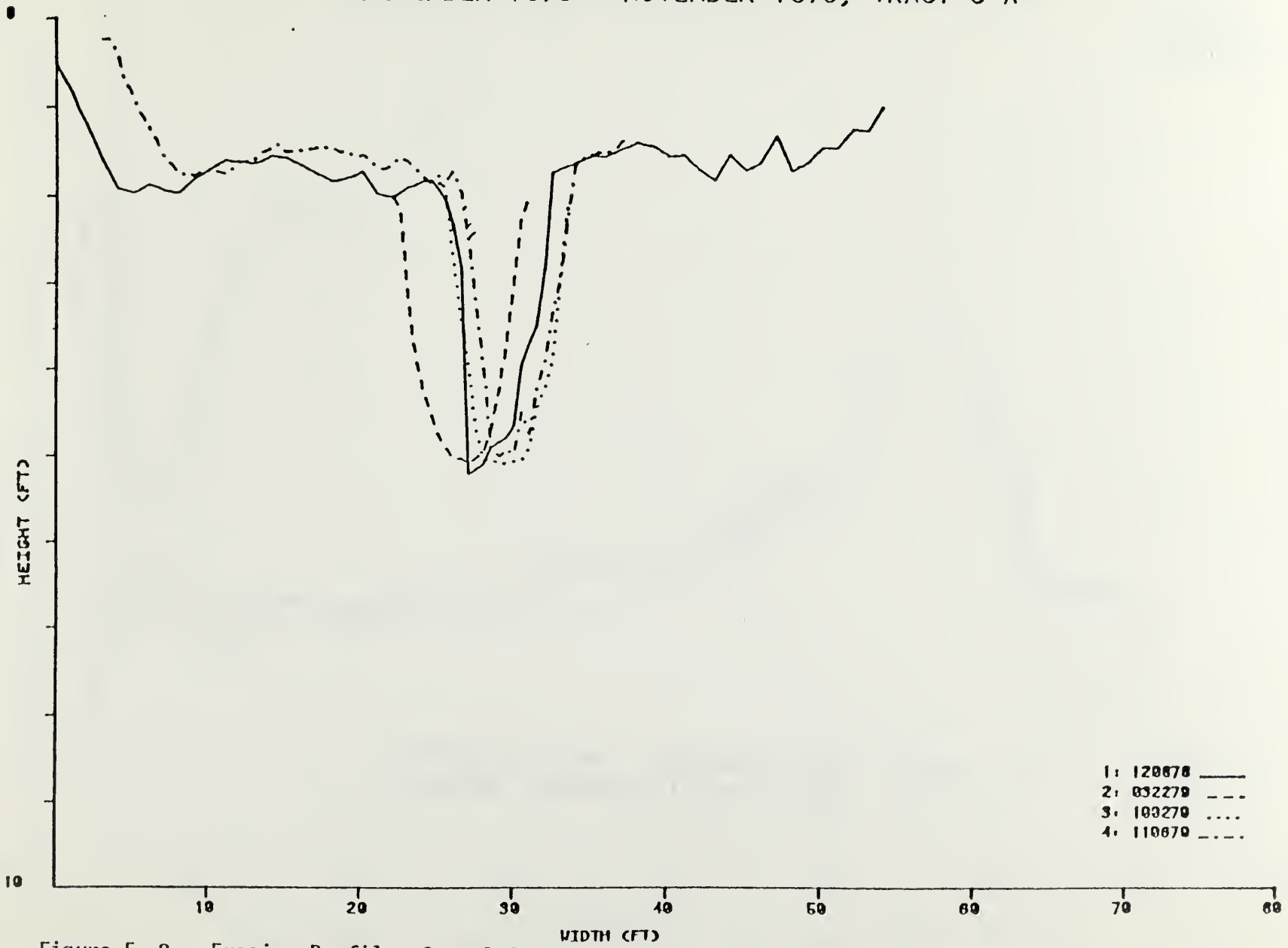


Figure 5- 8. Erosion Profile, Corral Gulch, December 1978- November 1979, Tract C-a

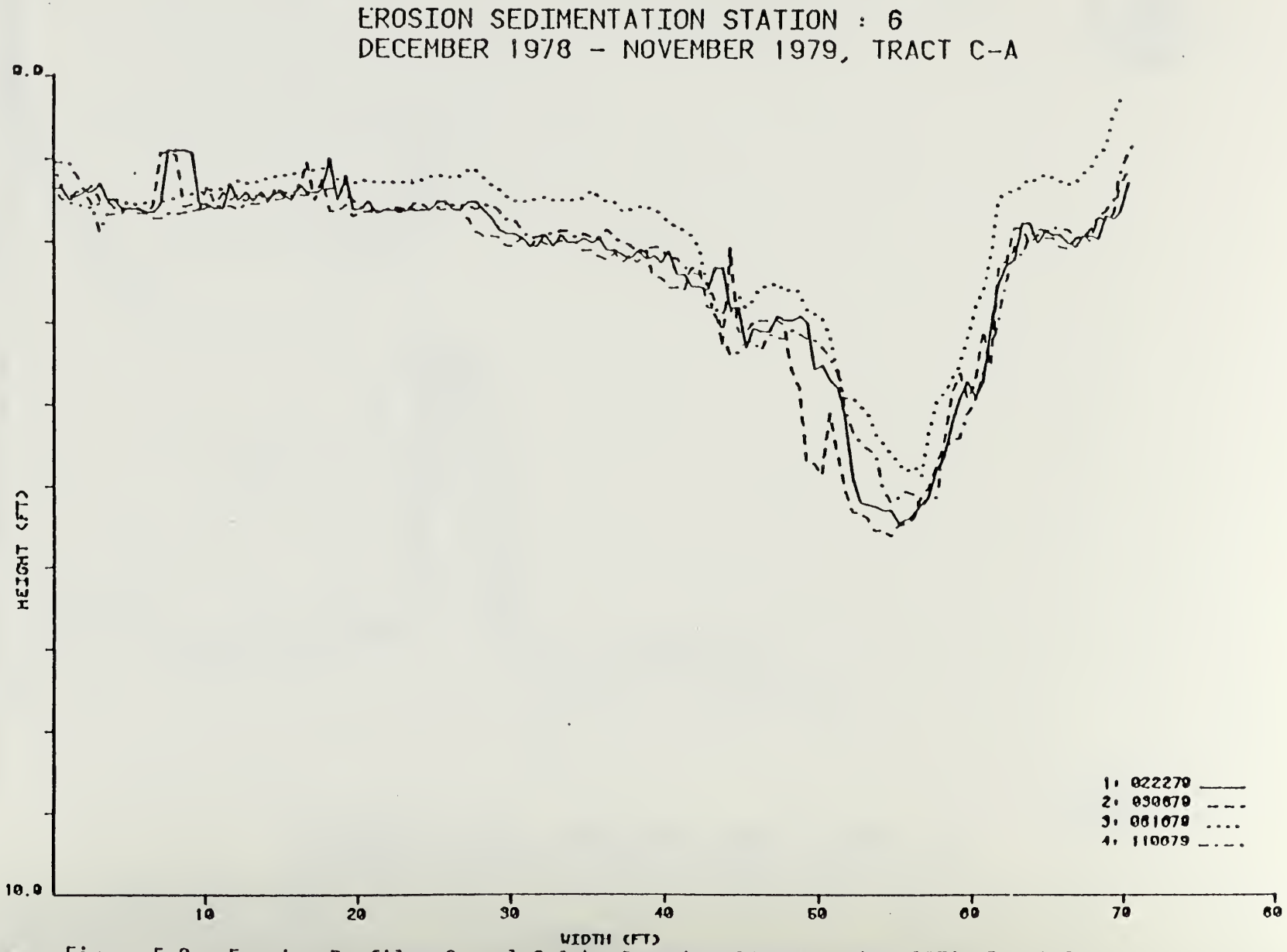


Figure 5-9. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

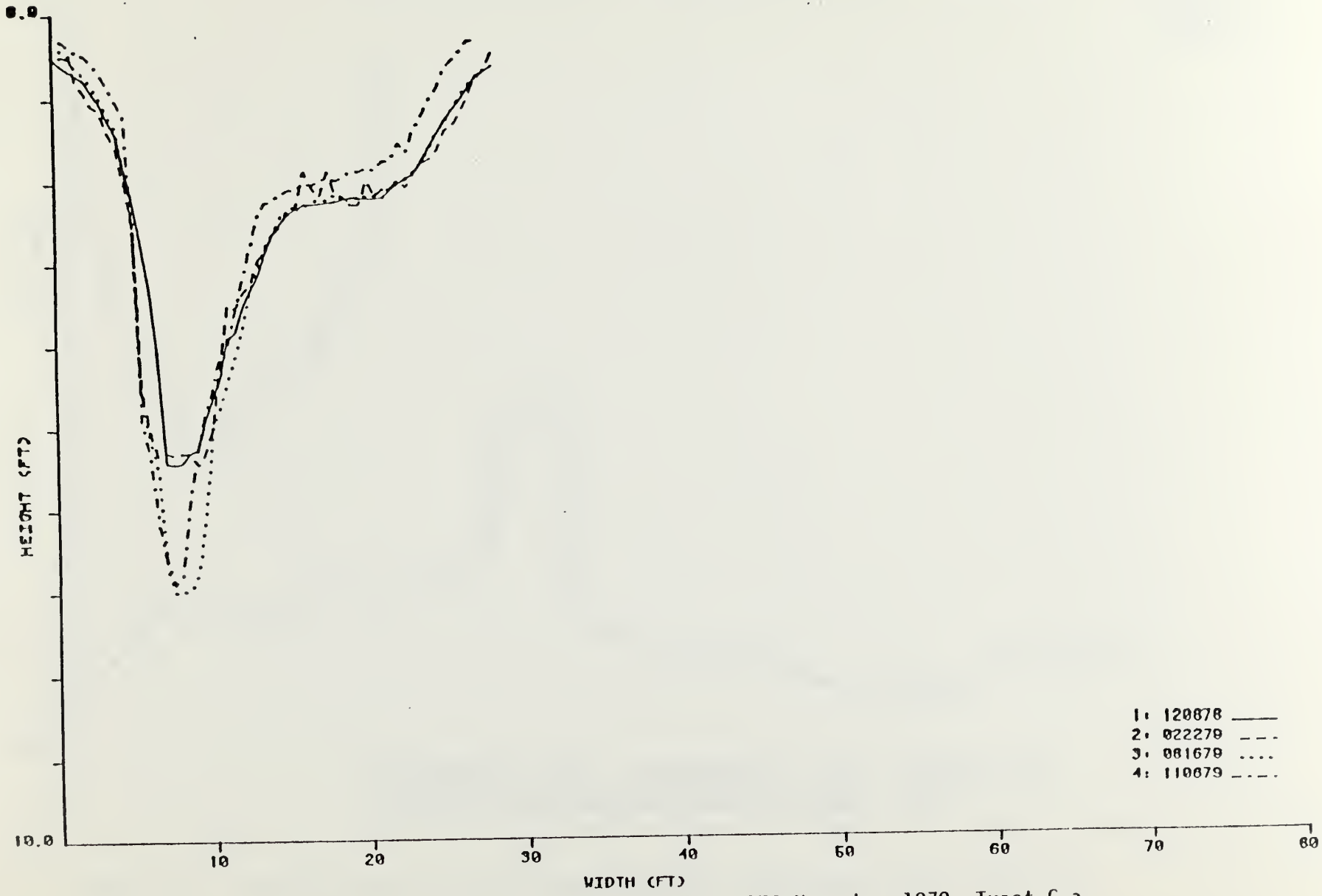


Figure 5-10. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

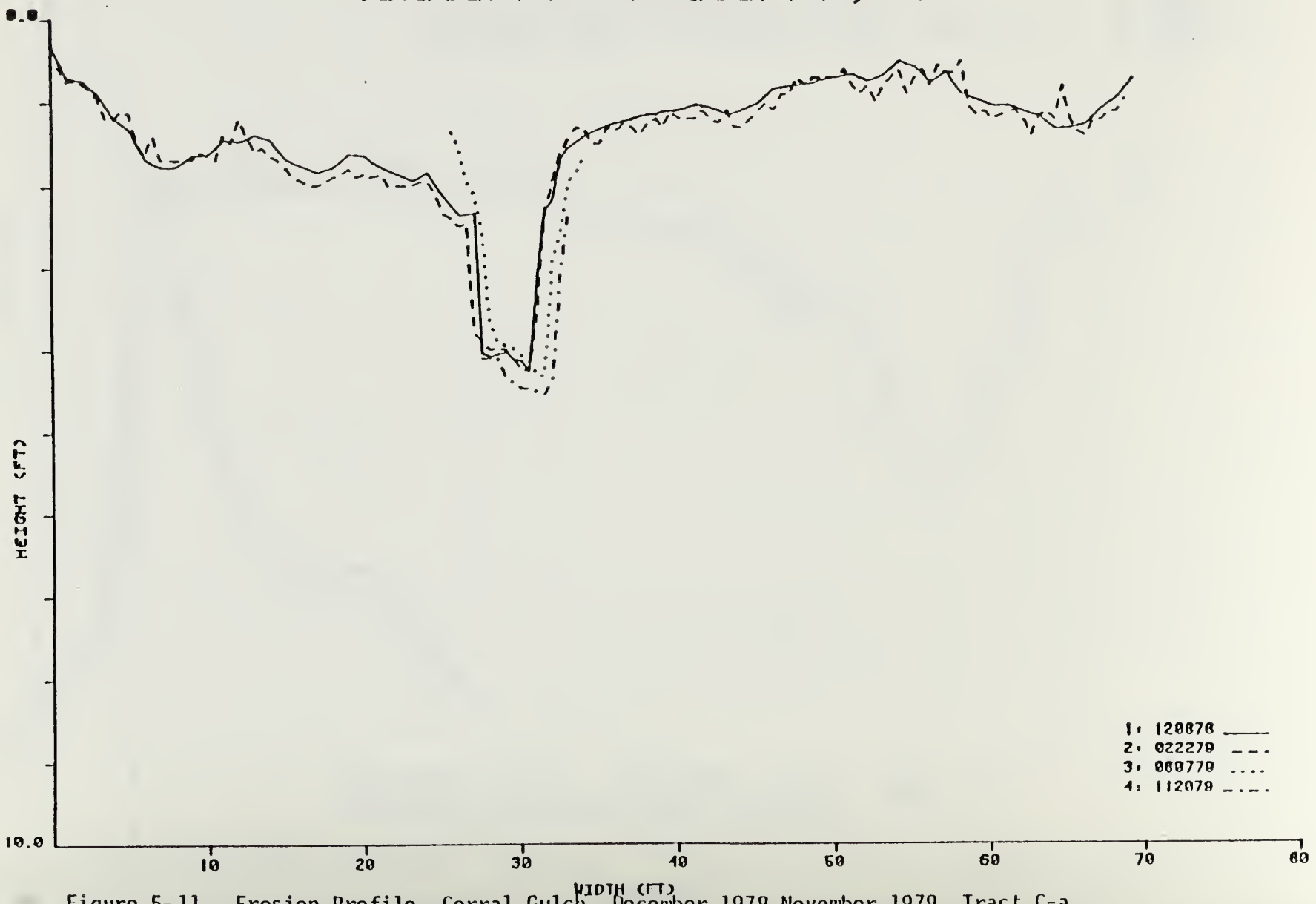


Figure 5-11. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

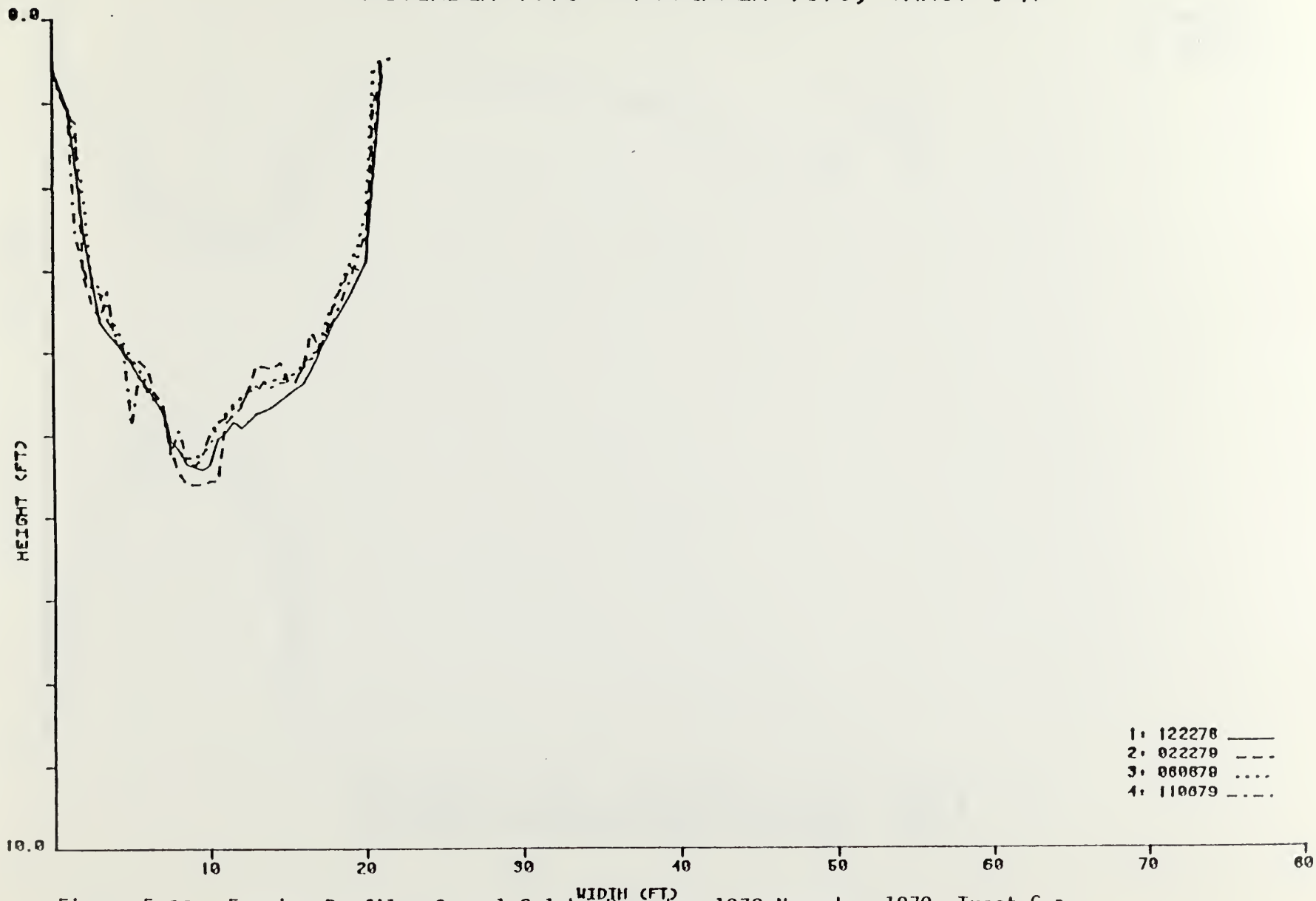


Figure 5-12. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

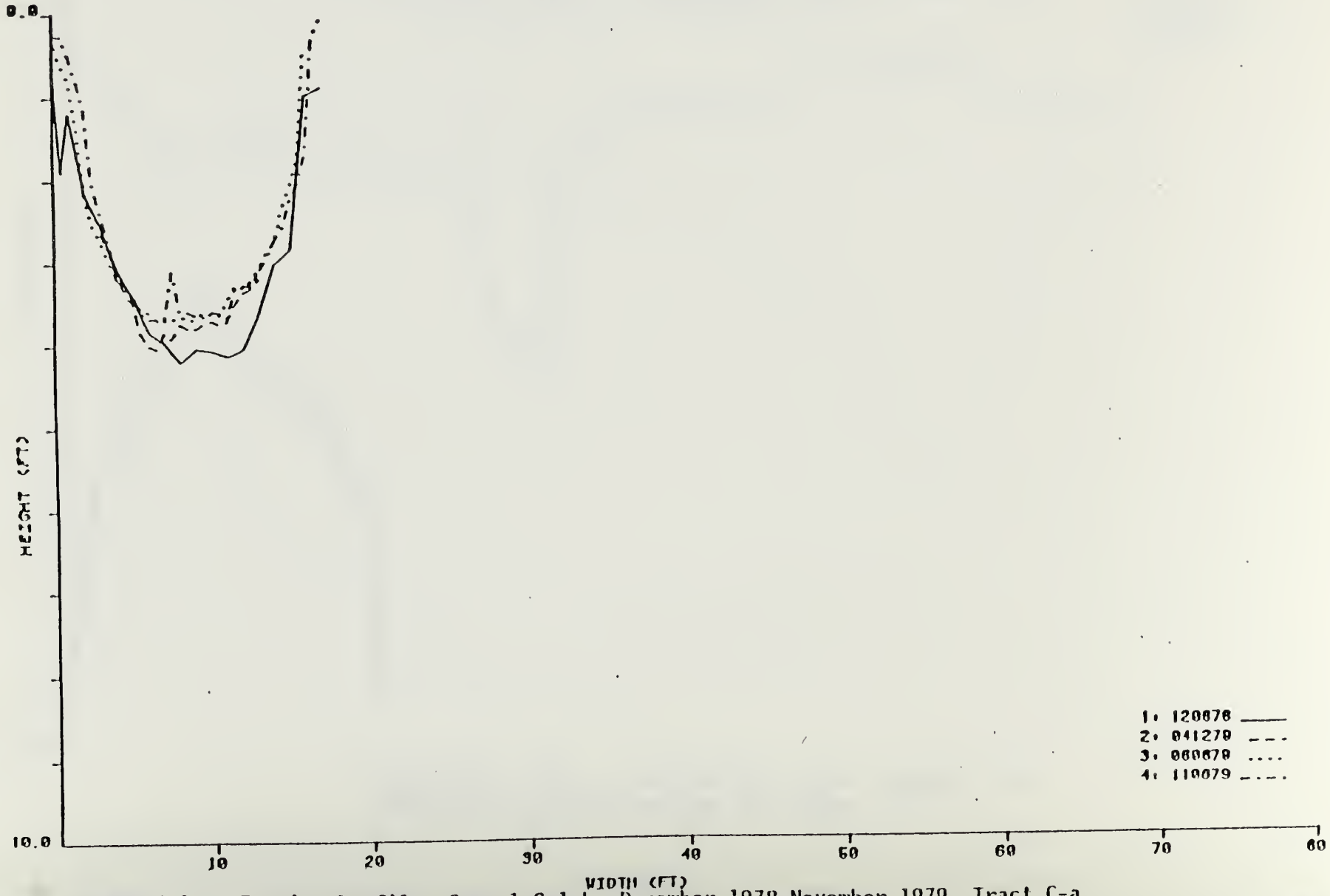


Figure 5-13. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

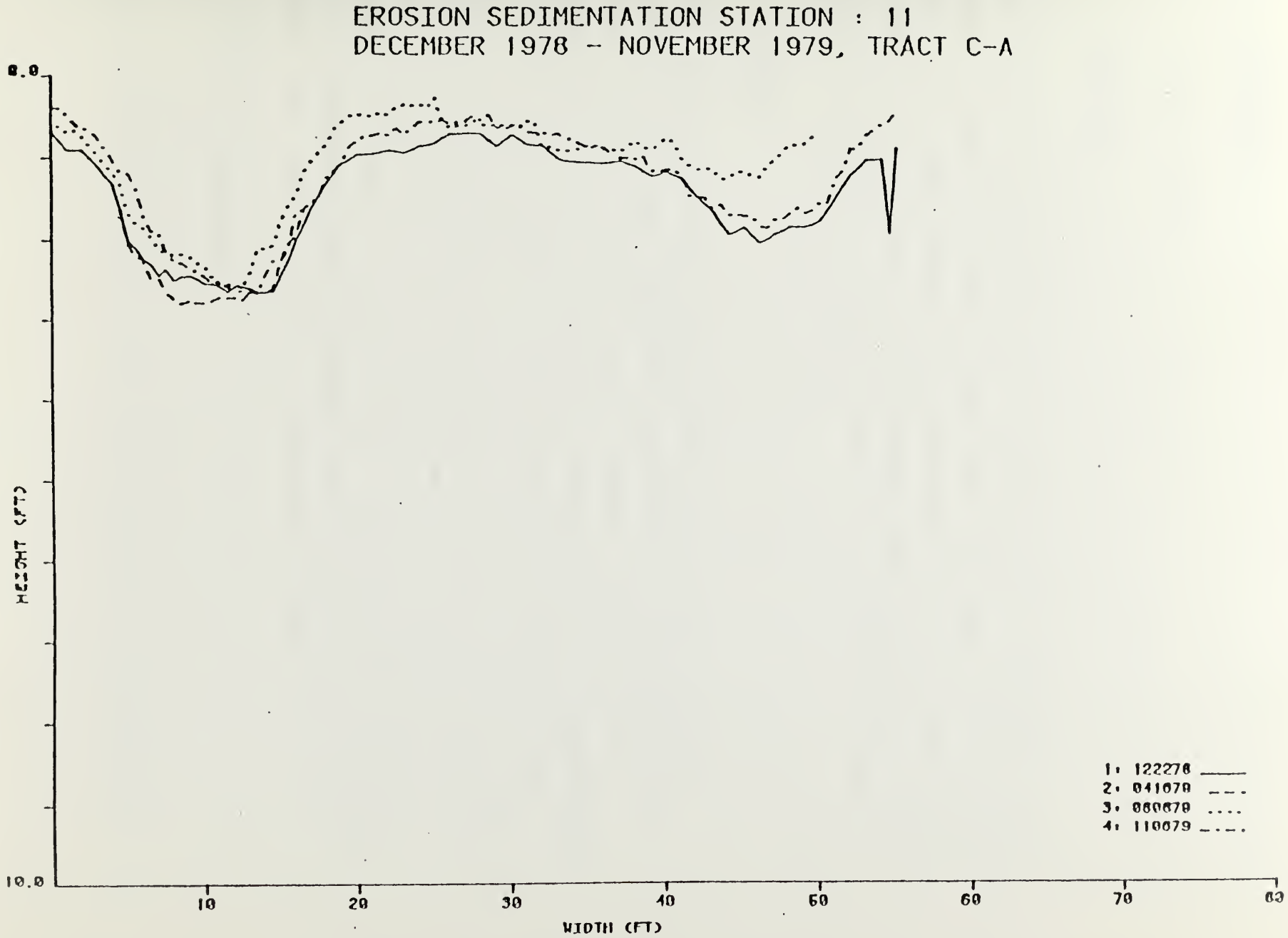


Figure 5-14. Erosion Profile, Corral Gulch, December 1978-November 1979, Tract C-a

5.2 GROUNDWATER

A. Alluvial Aquifers

1. Objectives

Alluvial aquifers are being monitored during the Modular Development Phase (MDP) to collect data on water levels and water quality. These data are then analyzed and compared to baseline period data. The purpose of this sampling analysis is to detect changes in the characteristics of the alluvial aquifers, to evaluate the significance of those changes observed and to assess the causes of the changes. An additional objective is to determine if lease and permit requirements are being met.

2. Methods

During the baseline period, seven shallow alluvial monitor holes were drilled and since then, 16 additional monitoring holes have been drilled. They are monitored according to several schedules. Water levels are measured daily in seven of these wells. Conductivity, pH, and temperature are measured twice per week in three of these seven holes and twice per month in the remaining four. In addition, samples are collected at three stations on a monthly basis and analyzed for pH, conductivity, temperature, alkalinity, bicarbonate, boron, and other major ions. Water levels are measured quarterly at five holes and other water quality constituents are measured at six holes on a quarterly basis. An extensive water quality analysis is conducted of samples taken semi-annually at nine of the alluvial monitor holes. The alluvial holes are described in Table 5-13.

3. Results and Discussion

a. Physical parameters - Six of the alluvial monitoring holes were found to be dry during the 1978-1979 reporting period. For the remaining

Table 5-13. Alluvial Aquifer Well Descriptions and Completion Intervals

Drainage	Well	Location	T.D.	Completion Intervals Dual Wells				Single Wells		Comments
				A	B	C	D	E	F	
Rinky Dink	G-S S13	S.B.	28	-	-	-	-	8	28	Dry
Box Elder Gulch	G-S S8	W.B.	50	-	-	-	-	10	50	---
	G-S S14	E.B.	50	-	-	-	-	10	50	Dry
Dry Fork of Corral Gulch	G-S S6	W.B.	12	-	-	-	-	3.5	12	Dry
Corral Gulch	G-S S7	W.B.	44	-	-	-	-	12.5	44	---
	G-S S25	C.T.	40	-	-	-	-	30	40	Dry
	G-S S26	C.T.	48	31	34	43	43	-	-	Dry
	G-S S27	E.B.	104	40	45	88	93	-	-	---
	G-S S27A	E.B.	16	5	15	-	-	-	-	Dry
	G-S S11	O.T.	66	34	39	50	58	-	-	---
	G-S S11A	O.T.	45	27	37	30	40	-	-	Sporadically Dry
	G-S S24	O.T.	75	-	-	-	-	55	75	---
Yellow Creek	G-S S28	O.T.	35	10	15	25	30	-	-	*
	G-S S28A	O.T.	36	11	16	26	31	-	-	*
	G-S S29	O.T.	43	15	20	33	38	-	-	*
	G-S S29A	O.T.	44	17	22	34	39	-	-	*

E.B. = near East Boundary of Tract

W.B. = near West Boundary of Tract

S.B. = near South Boundary of Tract

C.T. = near Center of Tract

O.T. = Off Tract

* = Well locations lost during personnel change, G-S S28 found in September and G-S S29 locations are still lost.

Note: All measurements are in feet.

alluvial holes, the physical data which were obtained during this reporting period are stream location going from upstream to downstream on Box Elder Gulch, Corral Gulch and Yellow Creek respectively.

G-S S8 is located in Box Elder Gulch at the west boundary of the Tract and reflects the condition of alluvial water entering the Tract. The plots of physical data for G-S S8 are shown on Figures 5-15 through 5-18. Due to a change in the scope of work in July, monthly measurement of physical parameters were discontinued at this hole. Therefore the data available are for December 1978 through July 1979. Water levels measured at this hole indicate seasonal fluctuations. Water levels during the winter months remained relatively constant. Beginning in April, the water level rose dramatically to a peak in June. This rise was accompanied by an increase in conductivity, an increase in temperature, and a decrease in pH. Typically, an increase in the water level in a well is accompanied by a decrease in conductivity. However the increase in conductivity in this case could indicate the presence of salts precipitated in the alluvium during evapotranspiration which are redissolved by early recharge in the spring.

G-S S7 is located in Corral Gulch at the west boundary of the Tract and reflects conditions of alluvial water entering the Tract. The physical data for G-S S7 are plotted in Figures 5-19 through 5-22. The data generally shows the same trends as G-S S8. Again, beginning in April, the recharge raised the water level and temperature and dissolved precipitated solids in the alluvium increasing the conductivity, and lowering the pH. While the water level peaked in July, the temperature peaked in October. Small fluctuation in water level in the fall were reflected in similar fluctuation in conductivity and a complimentary fluctuation in pH.

G-S S27 is located in Corral Gulch at the east Tract boundary and reflects conditions in alluvial water leaving the Tract. The physical data are plotted in Figures 5-23 through 5-26. The hydrograph features are dominated by a

16 foot drop in water level between March and September. The hydrograph behavior is not correlated with changes in discharge as might be expected. In February when reinjection was suspended, G-S S27 started to rise, but a month later it dropped. It is unclear why the water level changed. While the hydrograph shows no seasonal variation similar to G-S S7 upstream, the conductivity, temperature, and pH variation are very similar to those at G-S S7. The conductivities follow the same general trends with G-S S7, about 300 umhos higher than G-S S27. In particular, the behavior in the fall is almost identical. The temperature graph also follows the same general trends with G-S S27 possibly slightly warmer by 1^{o}C than G-S S7. Again behavior in the fall is almost identical. The pH's are almost identical all year long.

G-S S11 and G-S S11A are located in the Corral Gulch alluvium two miles downstream from the east Tract boundary. The physical data are shown in Figures 5-27 through 5-42. All four hydrographs responded to changes in discharge to Corral Gulch as well as spring recharge. Water levels rose slowly after the discharge to Corral Gulch increased in February but increased sharply in May and began a slow decrease in June after the SIR Gulch and spring recharge was over. A portion of the discharge was diverted. The water level has remained low since the termination of the SIR test in September because reinjection has taken most of the mine drainage and well water. The conductivity in the shallow wells increased with a rise in water level last summer, but also increased when the water levels continued to decline last fall. The conductivity in the lower wells fluctuated randomly about an increasing trend throughout the reporting period. The temperature in the shallow wells increased slightly during the summer but did not exhibit the natural seasonal changes in temperature that the deep well did. The temperature in the deep wells followed almost identically the temperature profiles of the upstream alluvial well G-S S27 except the temperature was colder. The pH in all four wells were fairly constant throughout the reporting period with deep wells showing more random fluctuations than the upper wells.

G-S S24 is located in the Corral Gulch alluvium about three miles downstream from the east Tract boundary. The physical data is plotted in Figures 5-43 through 5-46. The hydrograph did not respond to increased discharge in February but showed a sharp reponse to spring recharge. The conductivity showed a decrease in late summer and early fall which may be due to the presence of fresh water in the aquifer, following the spring runoff. Temperature fluctuations are considerable, but no long-term change is apparent. Fluctuation in pH also occurred, but no long-term change is apparent.

Shallow and deep wells at both G-S S28 and G-S S28A are located in Yellow Creek alluvium approximately six and one-half miles downstream from the east Tract boundary. The physical data are plotted in Figures 5-47 through 5-53. The limited data indicate that the water levels in the alluvium have risen about 10 feet during the reporting period. Conductivity, temperature, and pH values were similar to those at G-S S24.

In summary, the physical parameters measured in the alluvial monitoring holes exhibit natural seasonal variations and some apparent impacts due to the oil shale development, associated with dewatering observed at G-S S27 and G-S S11. The primary impact of the discharge of dewatering water is to raise the water level in the alluvium and even out the seasonal fluctuations. Table 5-14 presents a comparison of report period data with baseline data from the alluvial monitoring holes. The static water level has risen about 10 feet and the conductivity has increased slightly but the temperature and pH are about the same.

Table 5-14. Comparison of Baseline Data and Report Period Data from Alluvial Monitoring Holes, Tract C-a

Baseline (1974-1976)

Hole	Depth (feet)	Static Water Level (ft)		Temperature (°C)		Conductivity (umhos)*	
		Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
G-S S7	44	21.6	2.5	9.22	2.9	1096	58.0
G-S S8	50	35.7	3.7	9.56	2.9	970	83.3
G-S S11	66	44.0	1.5	10.33	3.0	1796	187.5

Report Period (1979)

Hole	Depth (feet)	Static Water Level (ft)		Temperature (°C)		Conductivity (umhos)*	
		Mean	Stand. Dev.	Mean	Stand. Dev.	Mean	Stand. Dev.
G-S S7	44	25.2	1.6	10.29	2.5	**	**
G-S S8	50	36.9	7.8	8.75	2.1		
G-S S11	66	35.8	5.5	9.17	2.1		

* Geometric mean, standard deviation by method of moments.

**Program to manipulate data unavailable; results based on inspection of conductivity plots.

G-S S8 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

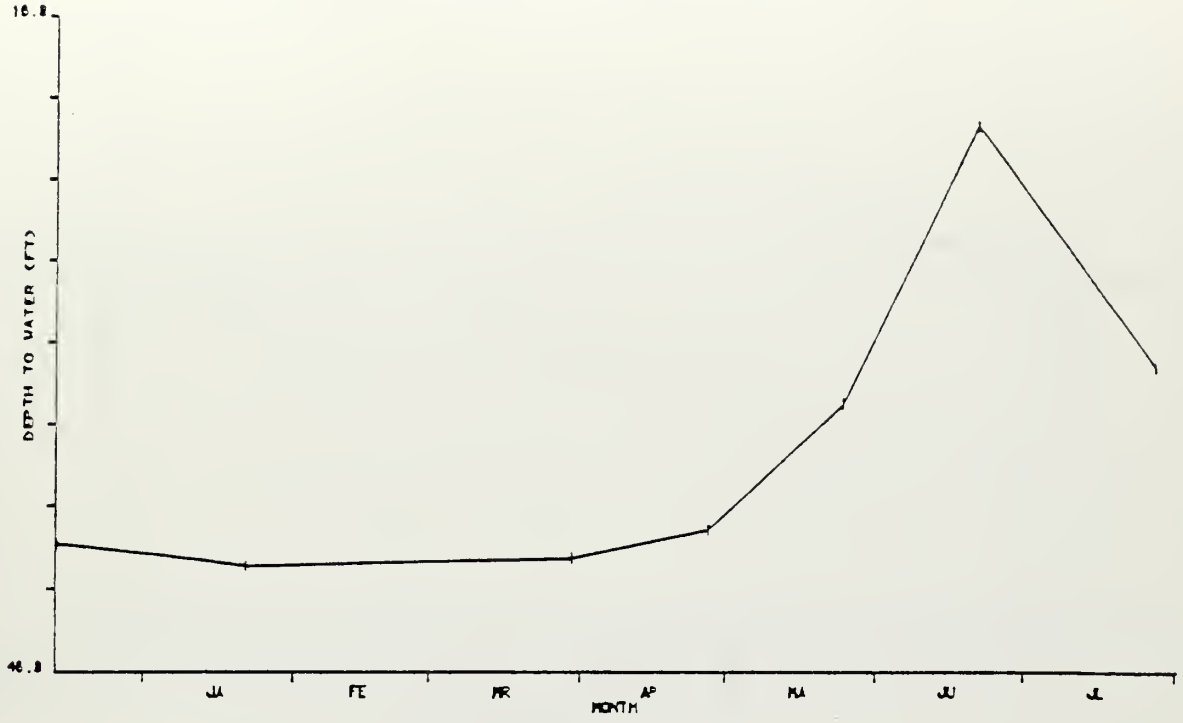


Figure 5-15

G-S S8 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

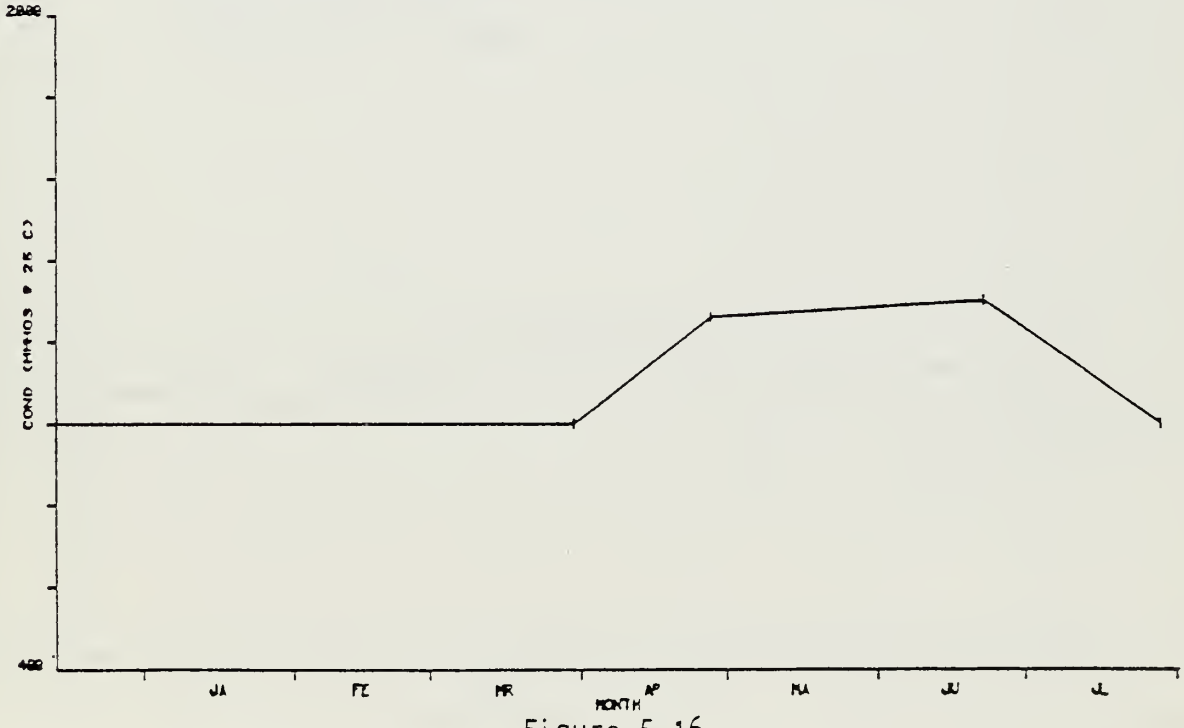


Figure 5-16

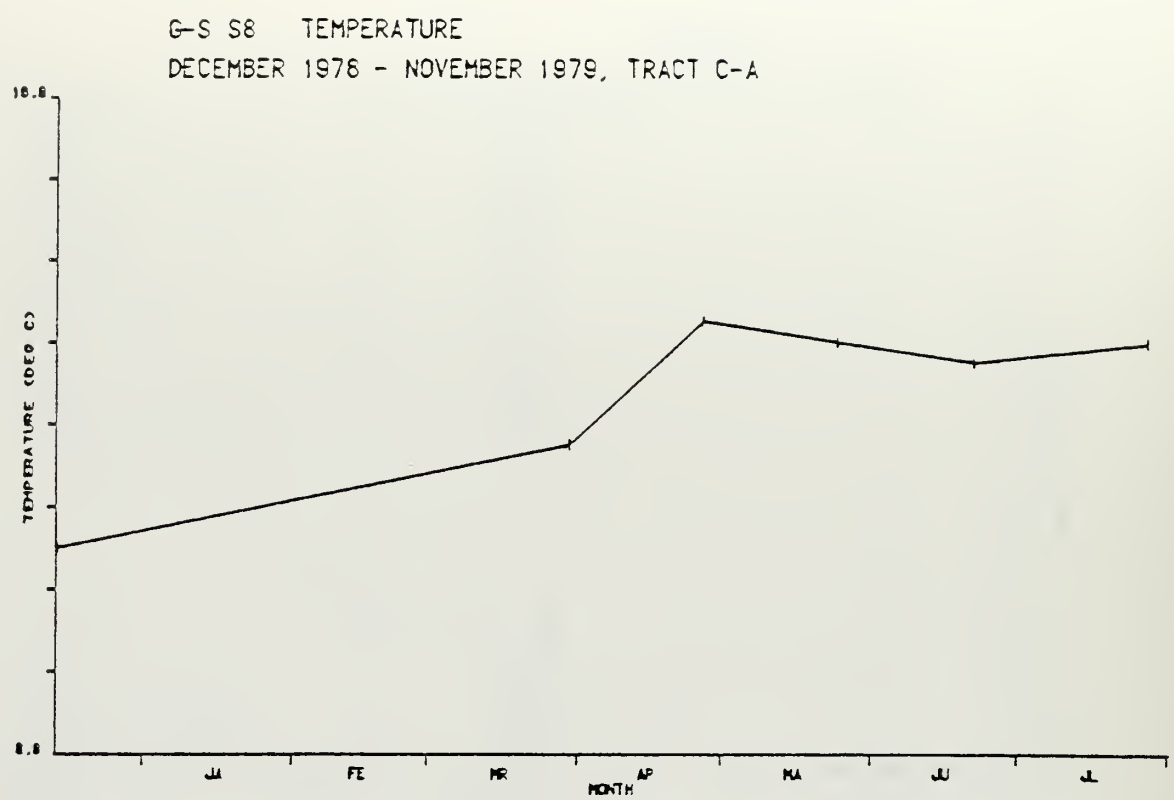


Figure 5-17

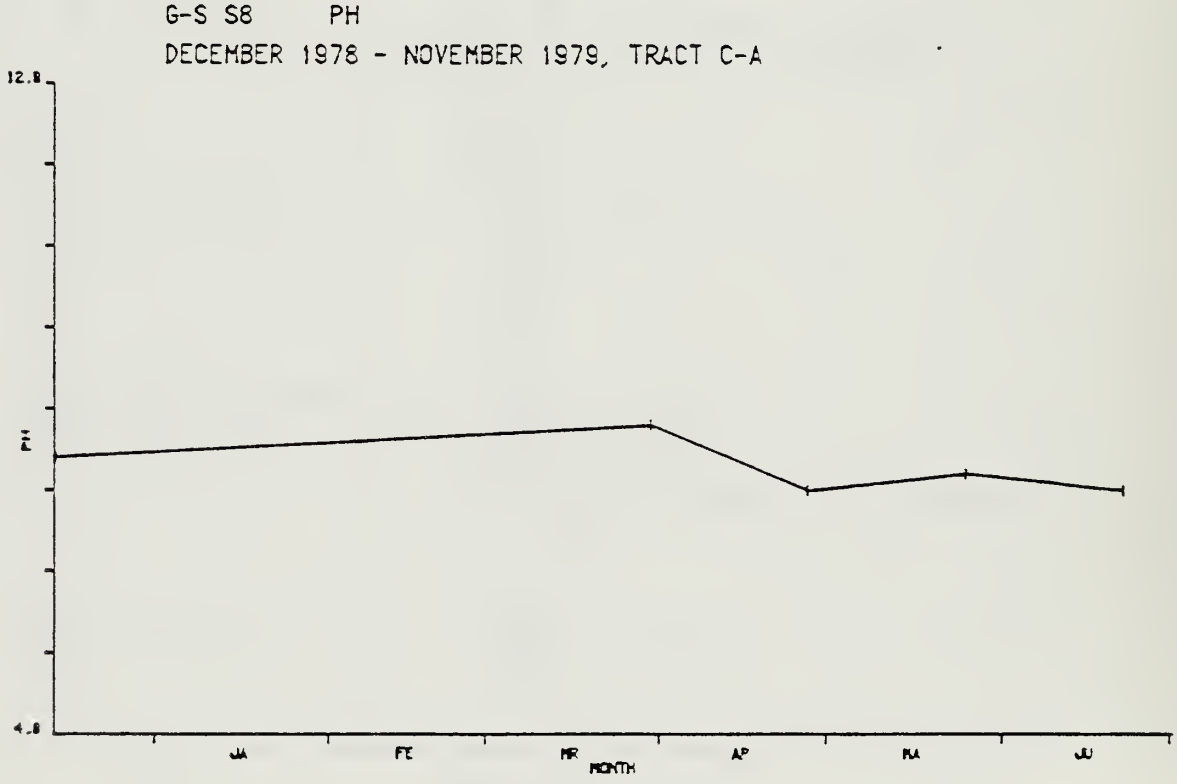


Figure 5-18

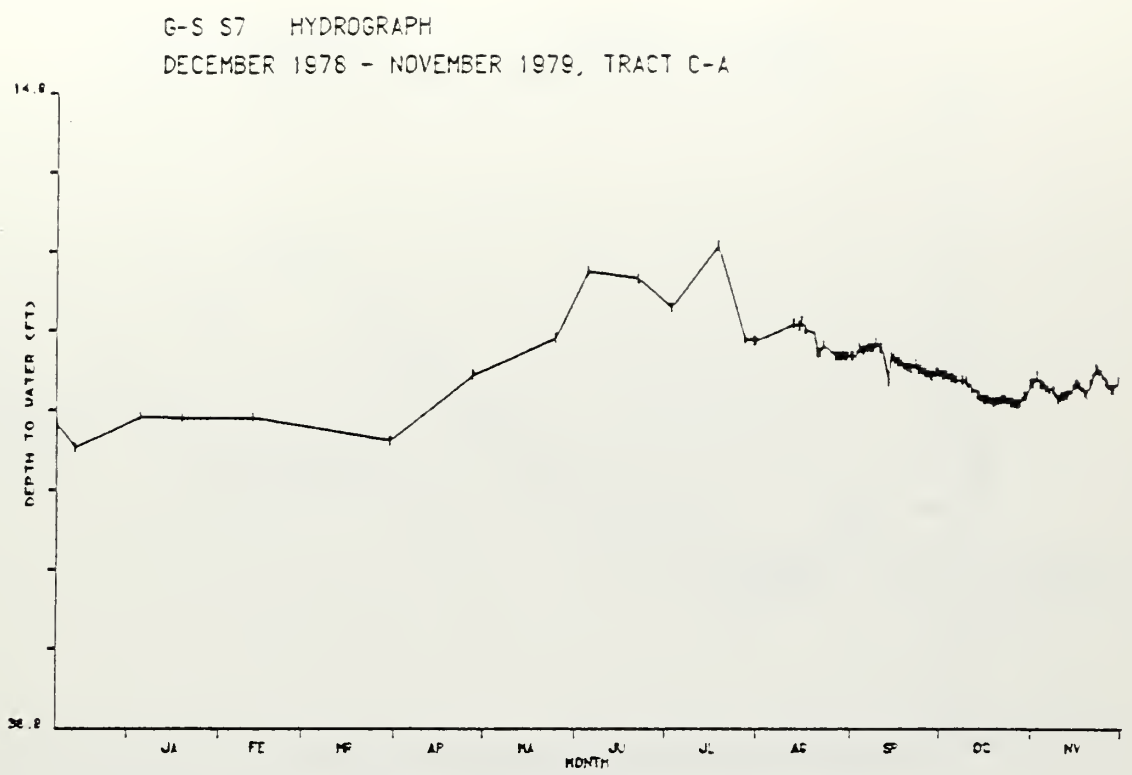


Figure 5-19

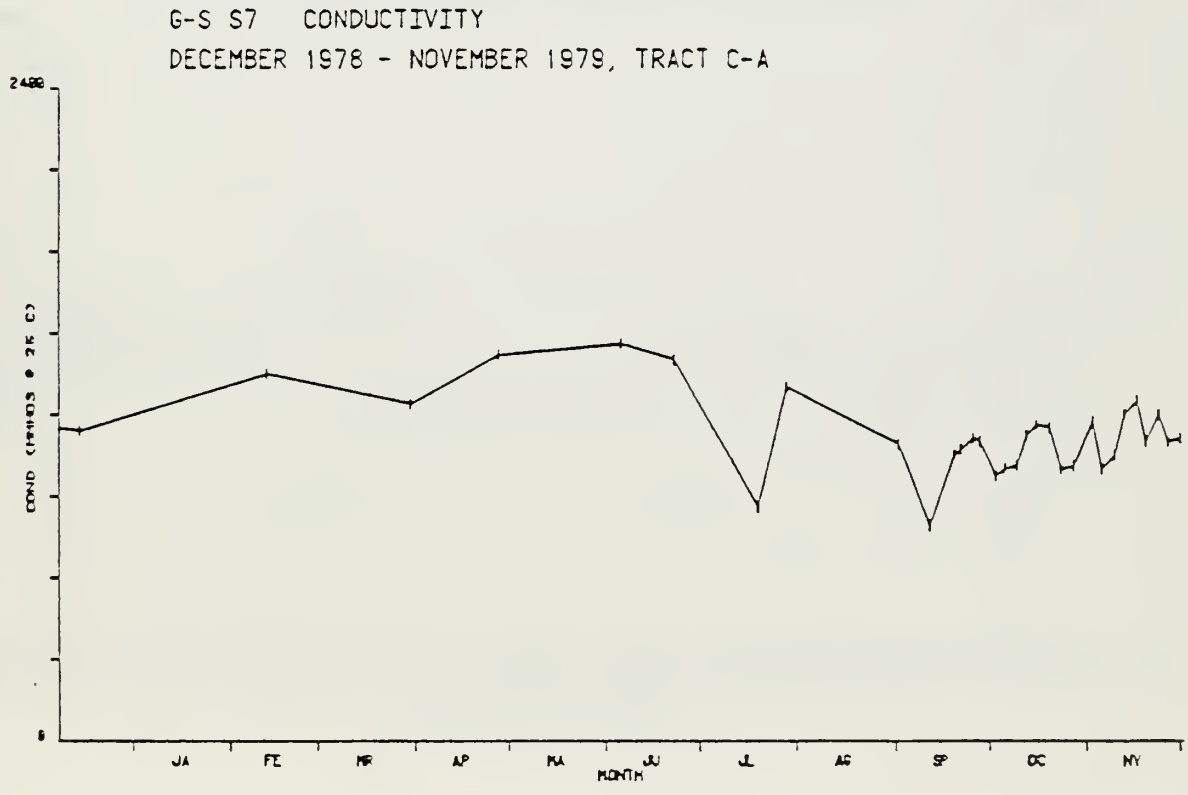


Figure 5-20

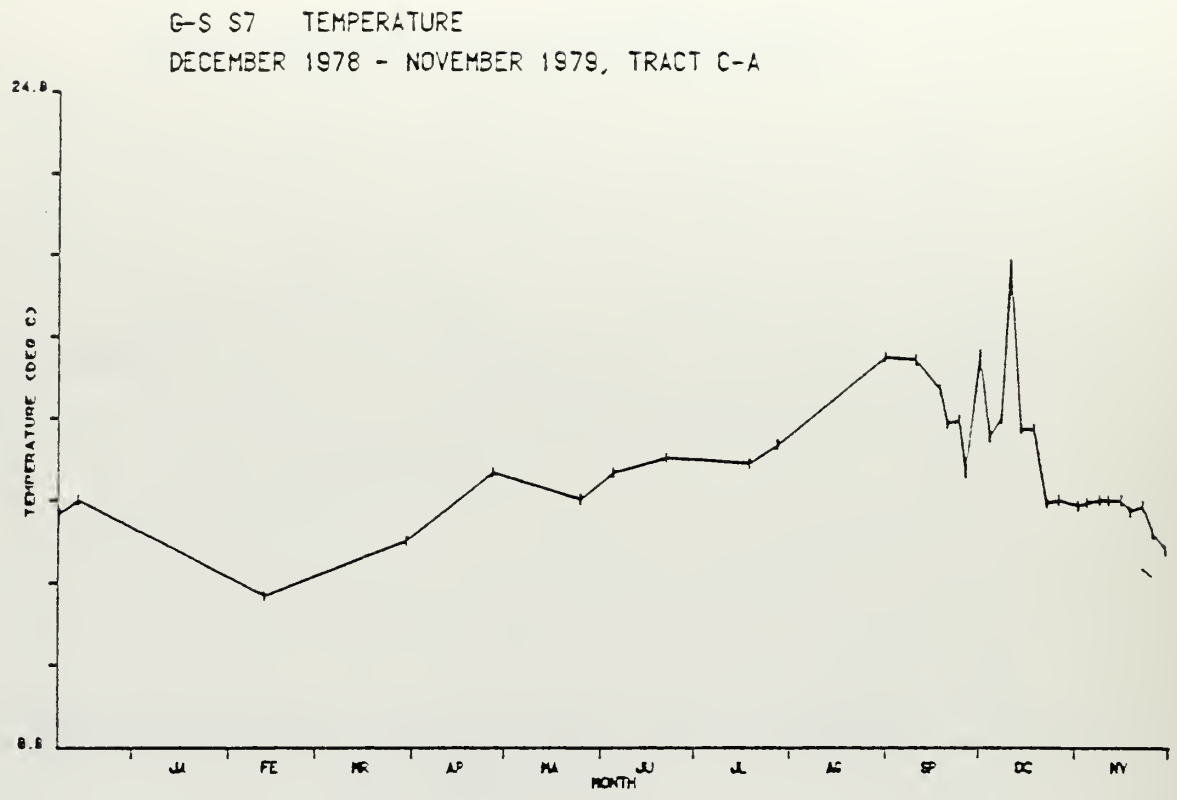


Figure 5-21

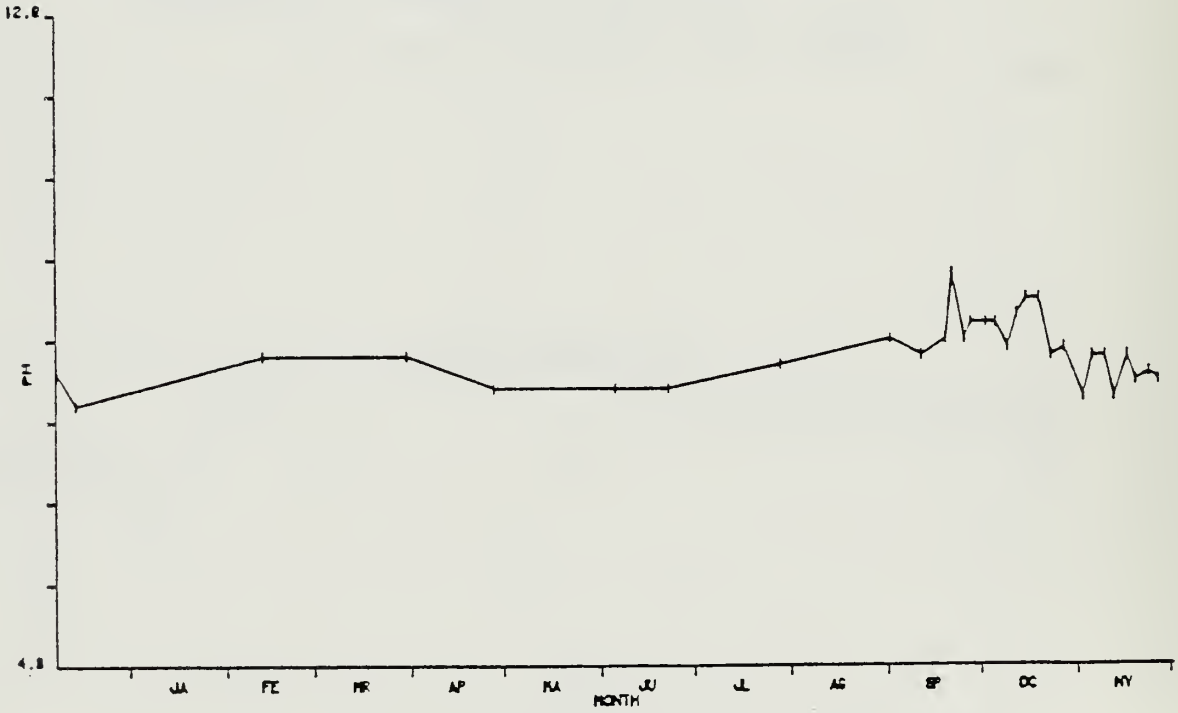


Figure 5-22

G-S S27 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

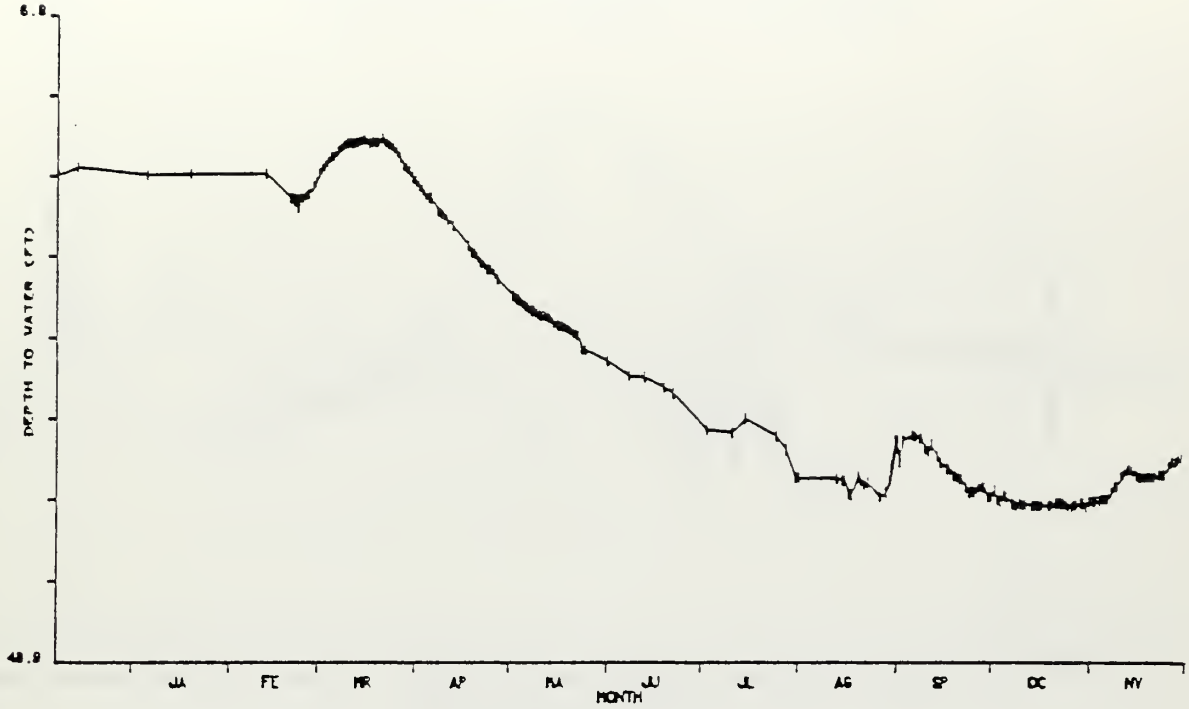


Figure 5-23

G-S S27 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

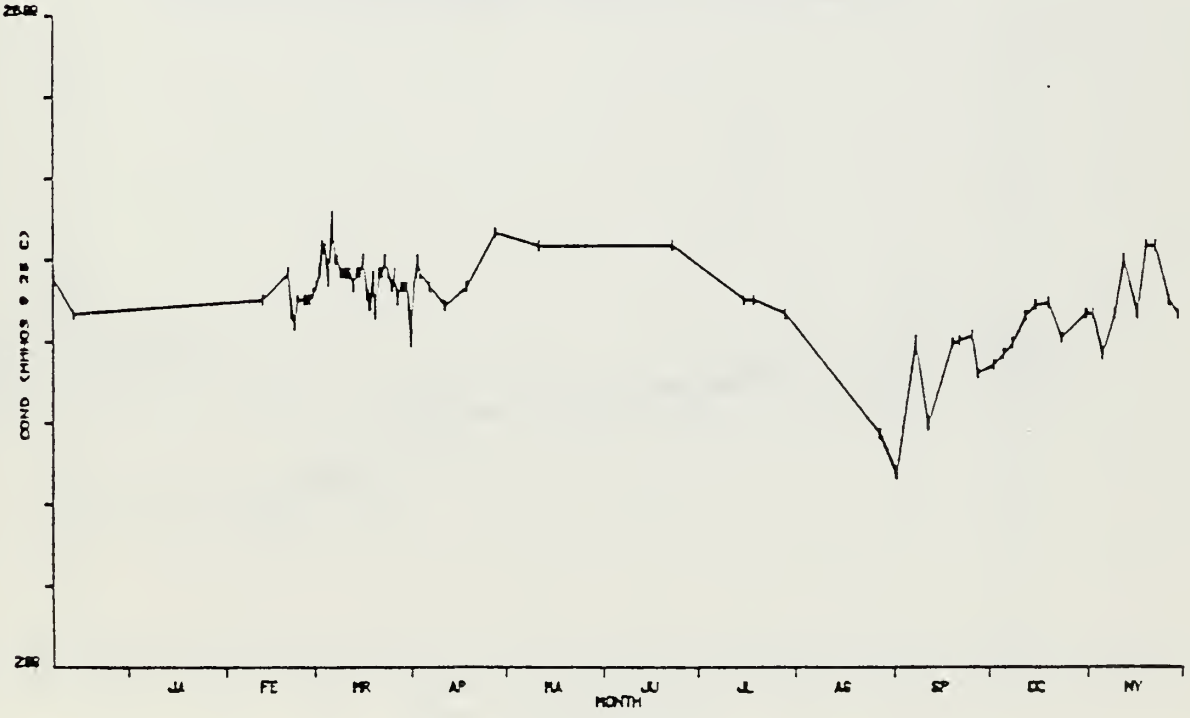


Figure 5-24

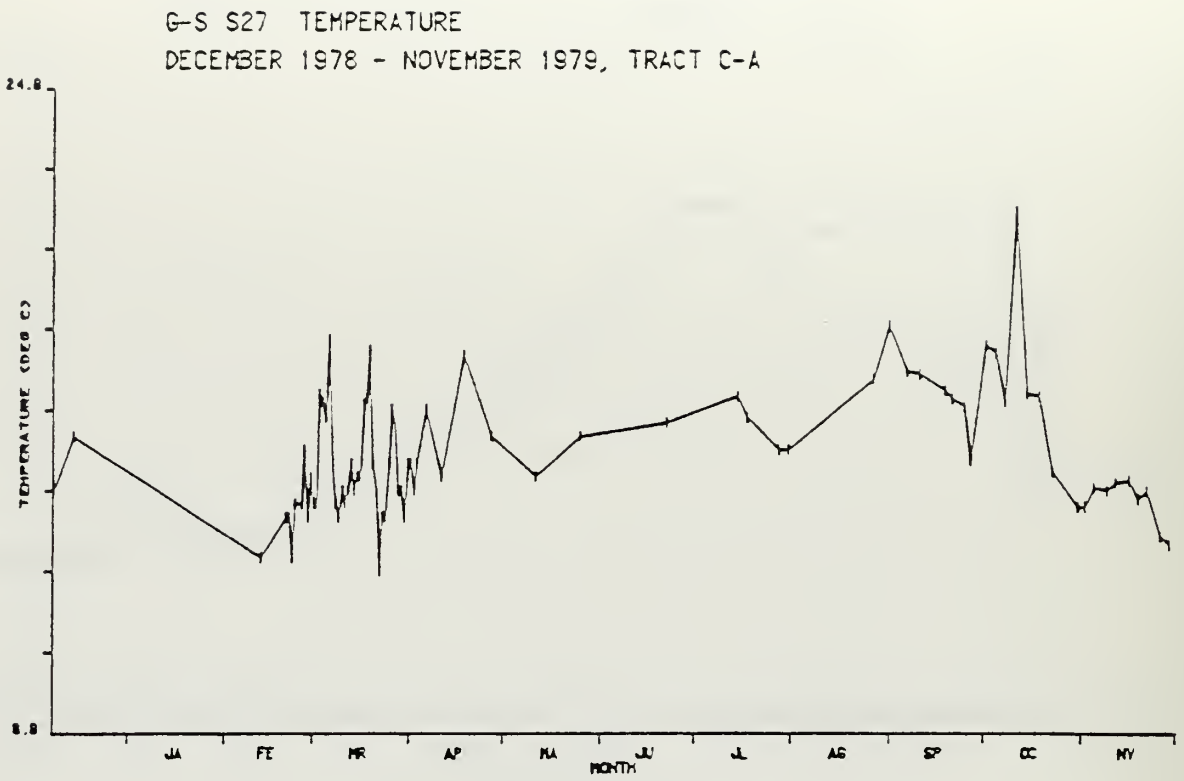


Figure 5-25

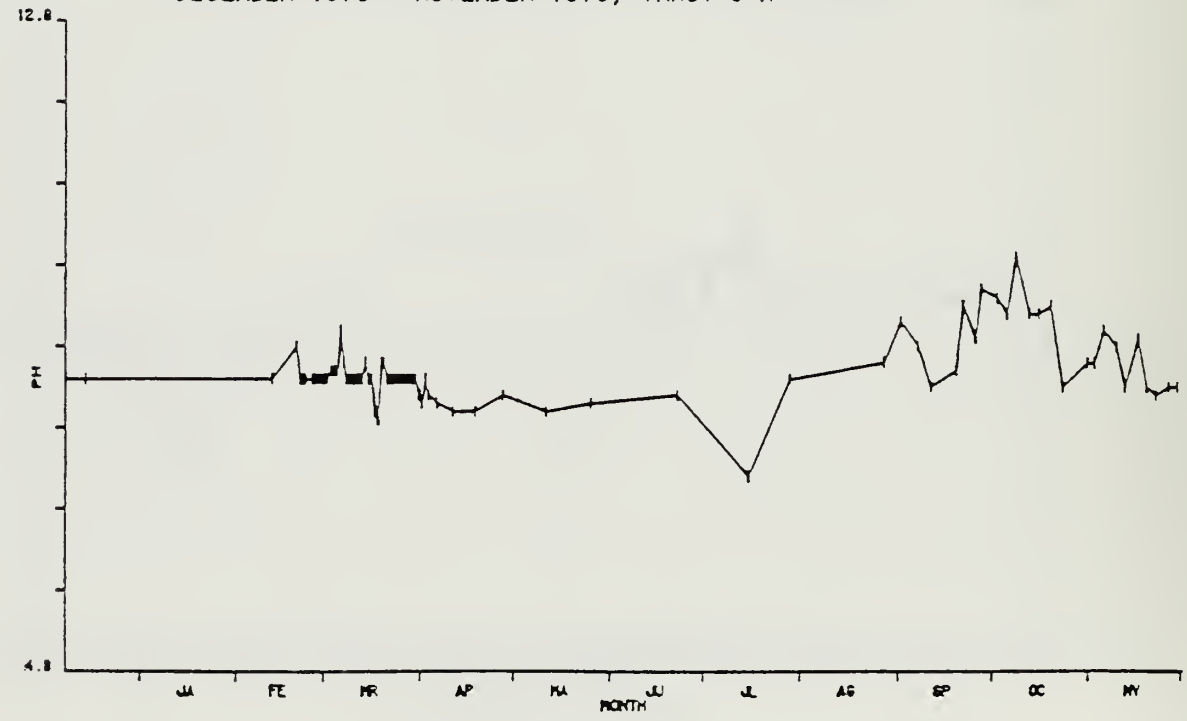


Figure 5-26

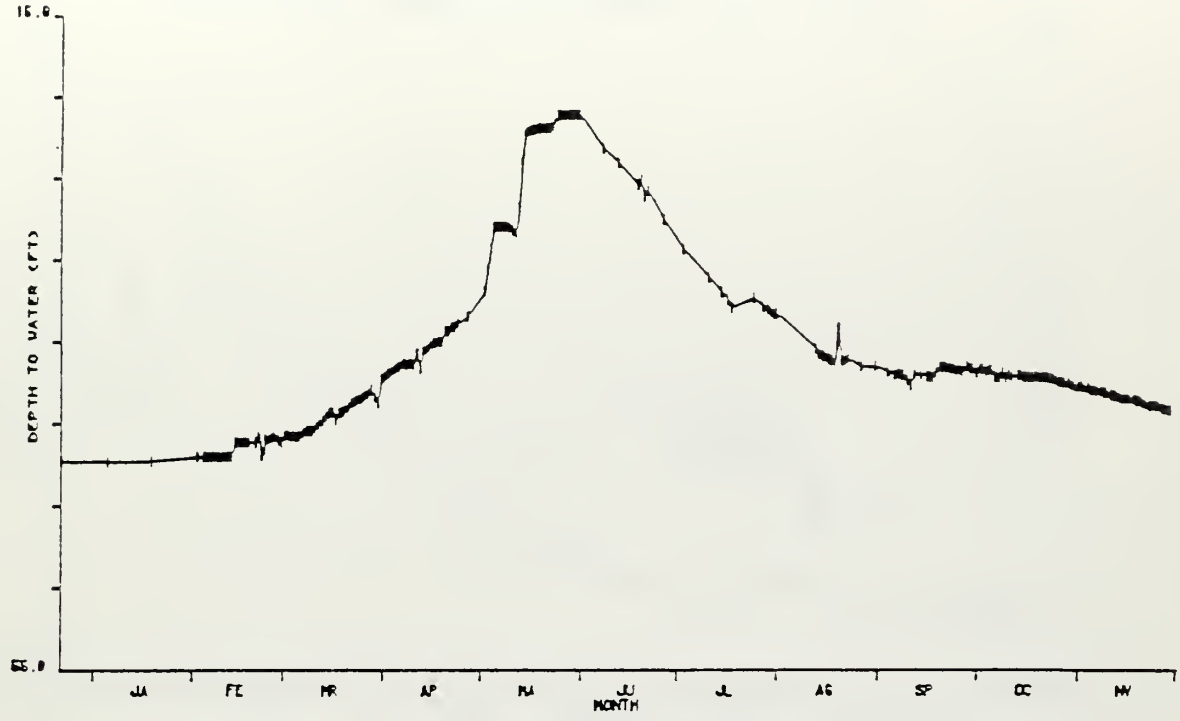


Figure 5-27

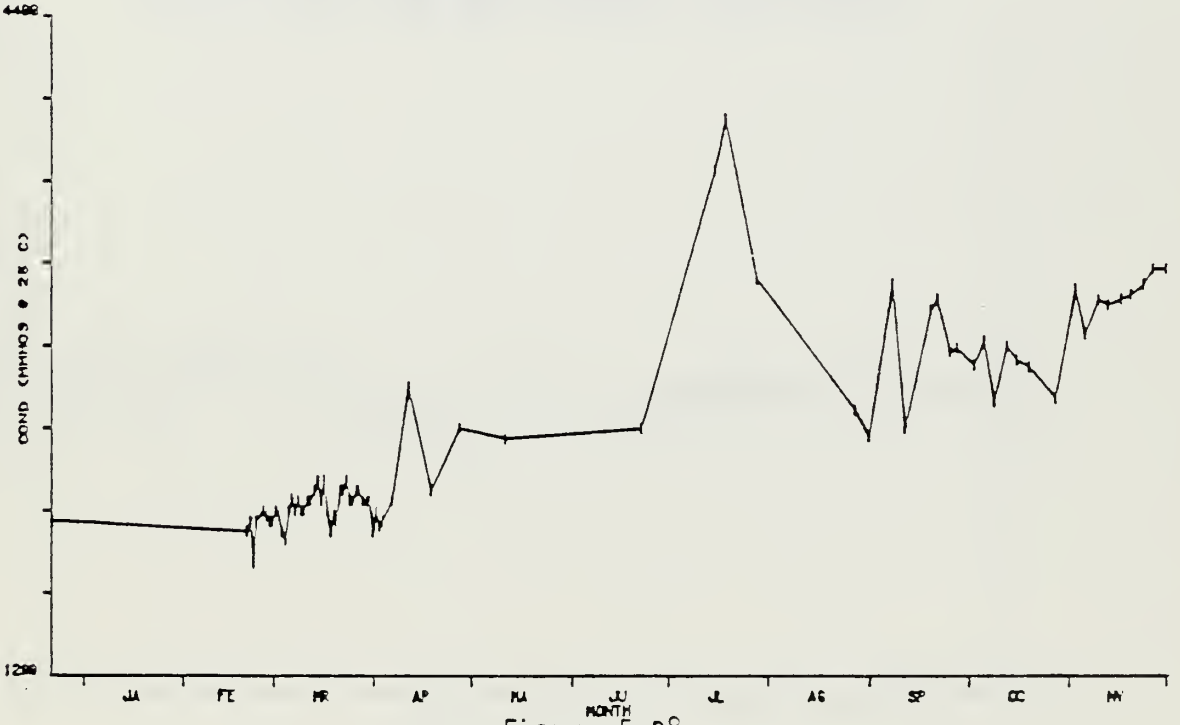


Figure 5-28

G-S S11 DEEP, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

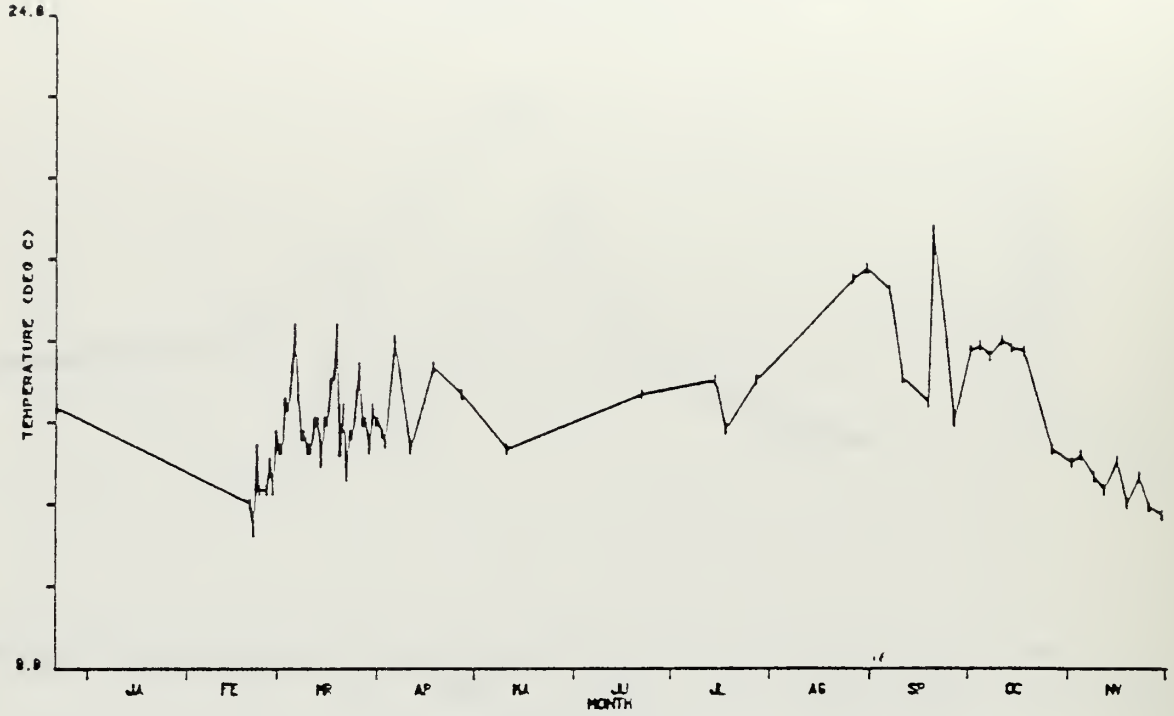


Figure 5-29

G-S S11 DEEP, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

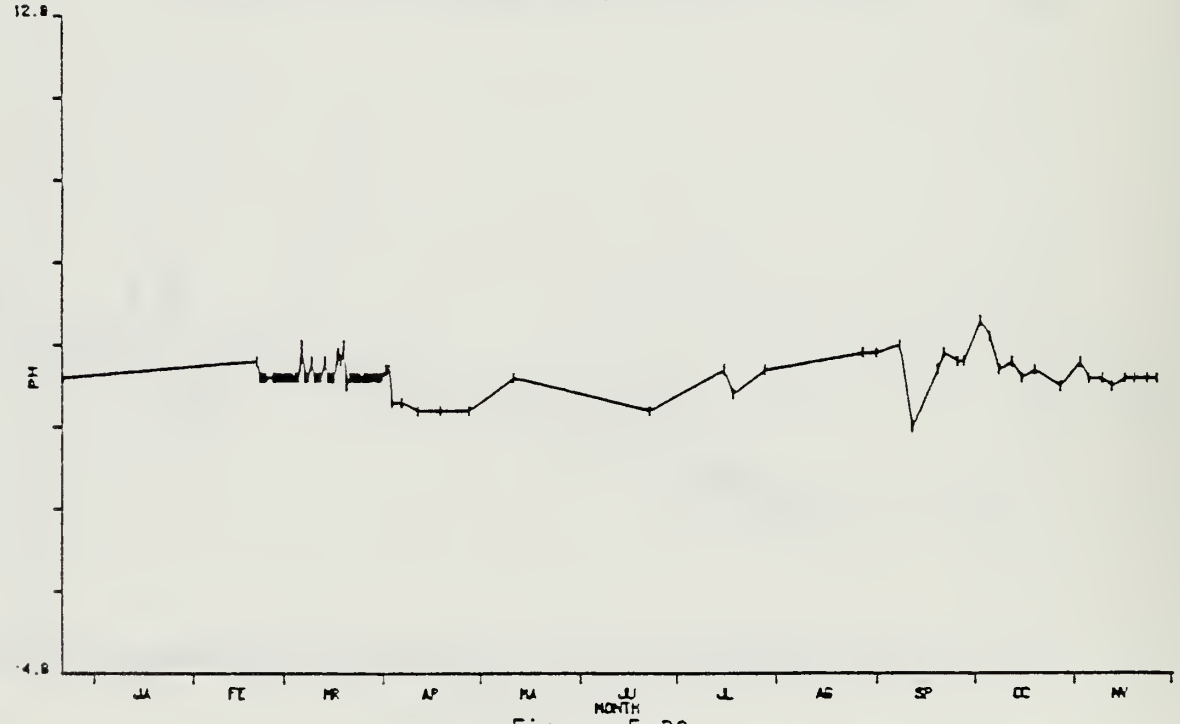


Figure 5-30

G-S S11 SHALLOW, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

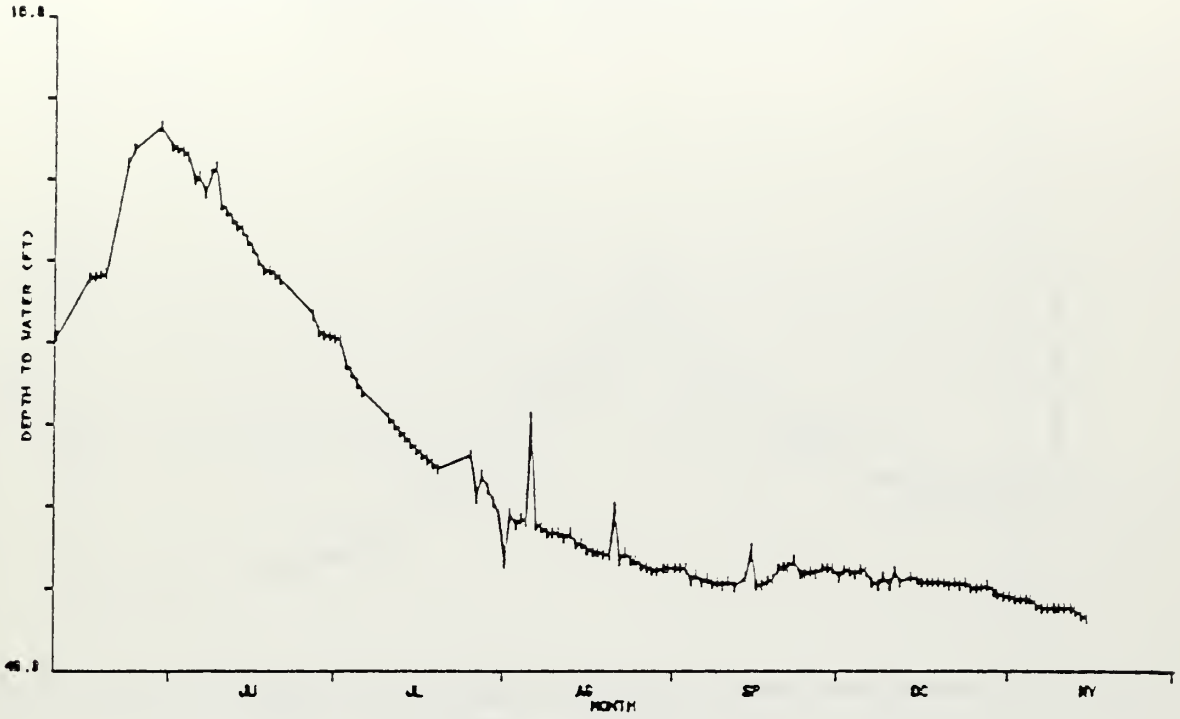


Figure 5-31

G-S S11 SHALLOW, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

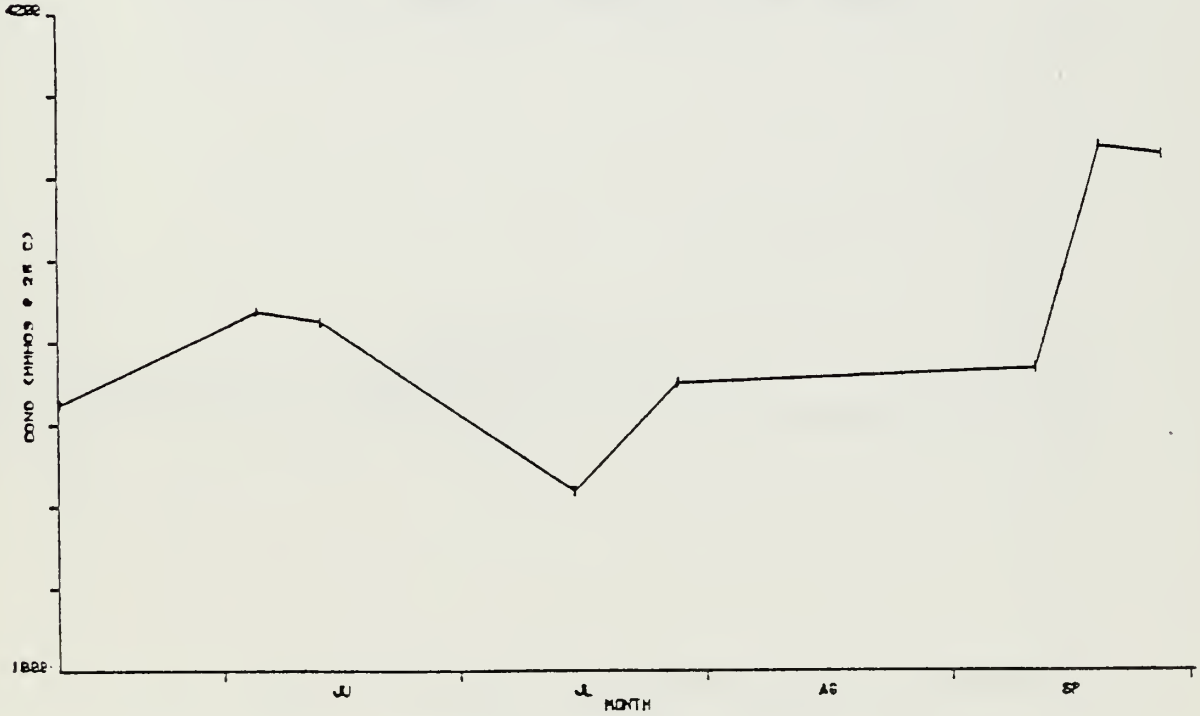


Figure 5-32

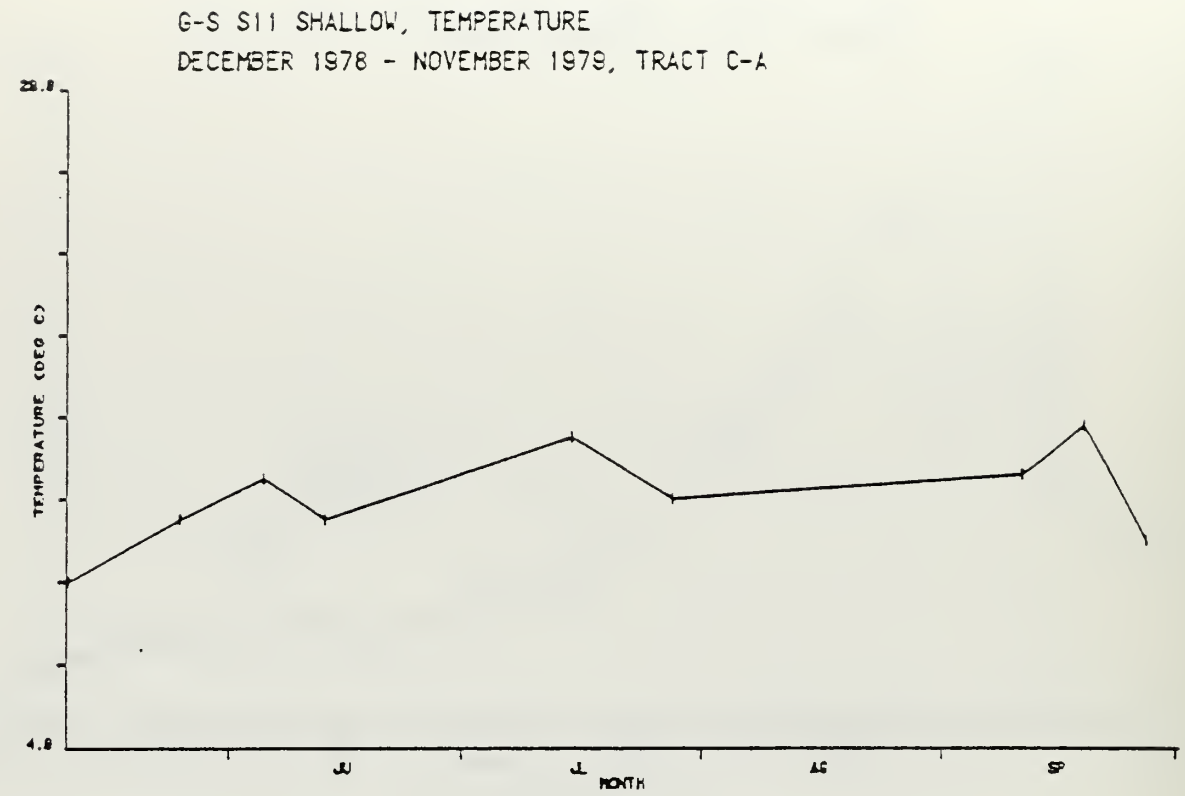


Figure 5-33

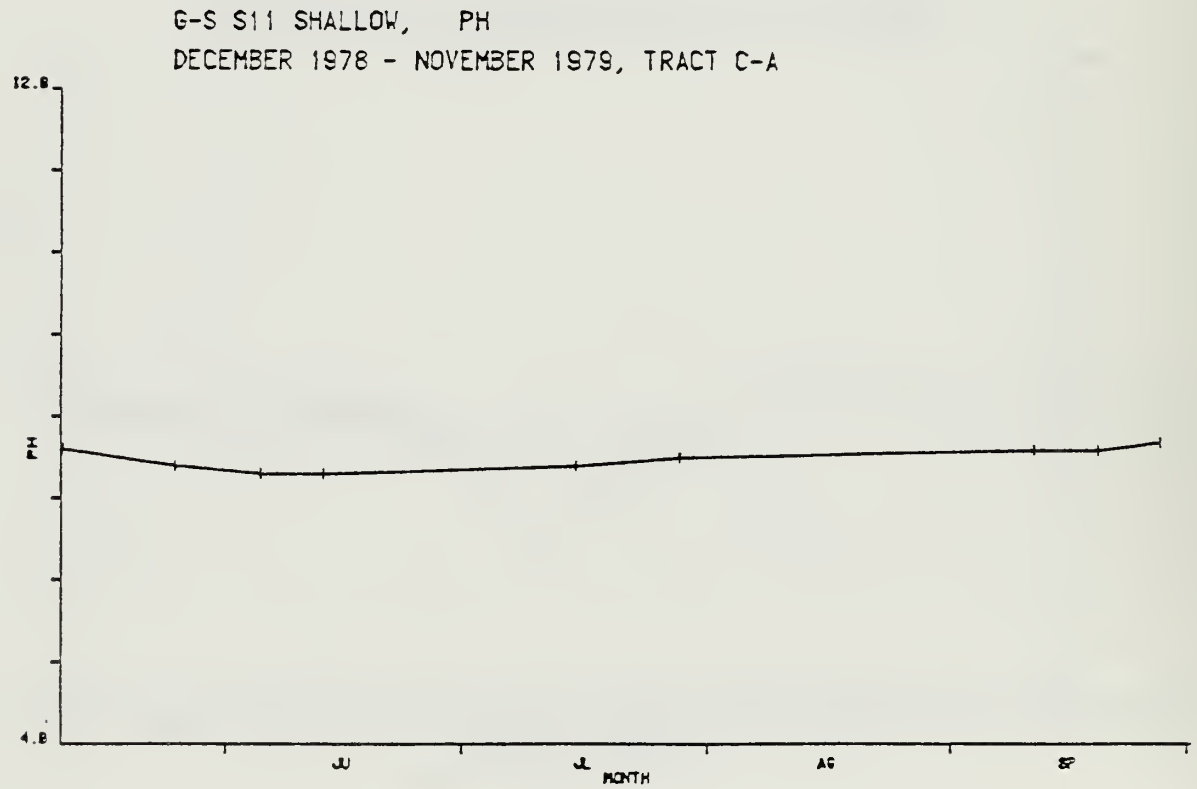


Figure 5-34

G-S S11A DEEP, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

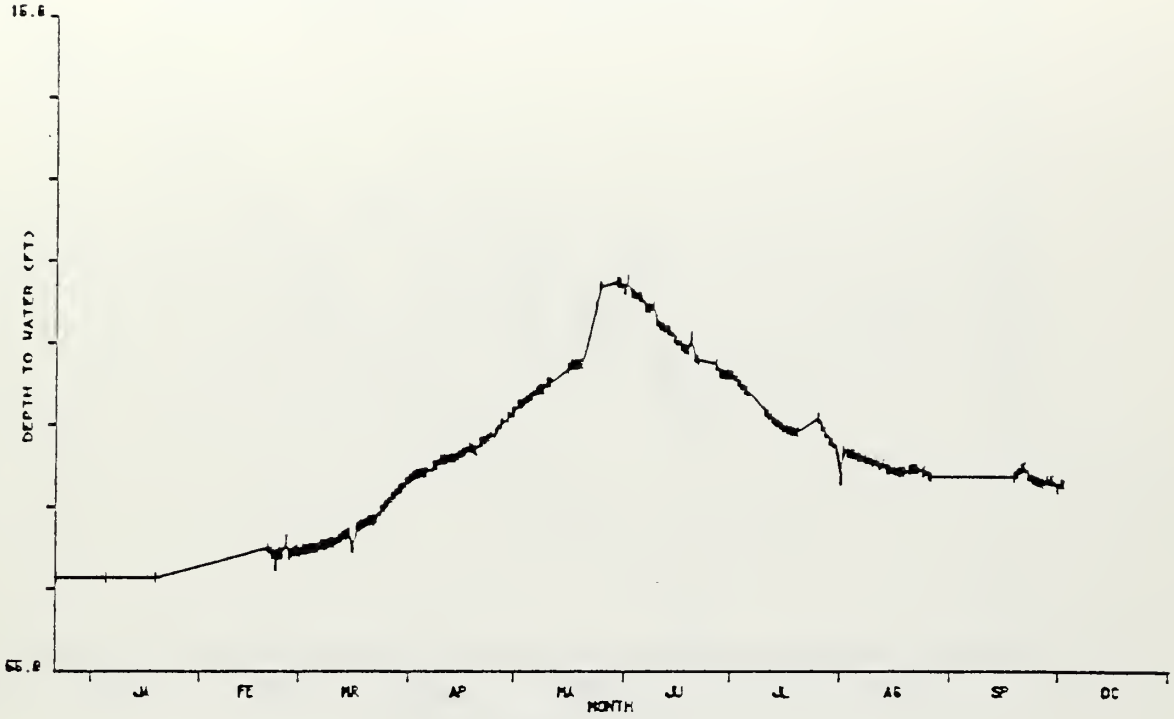


Figure 5-35

G-S S11A DEEP, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

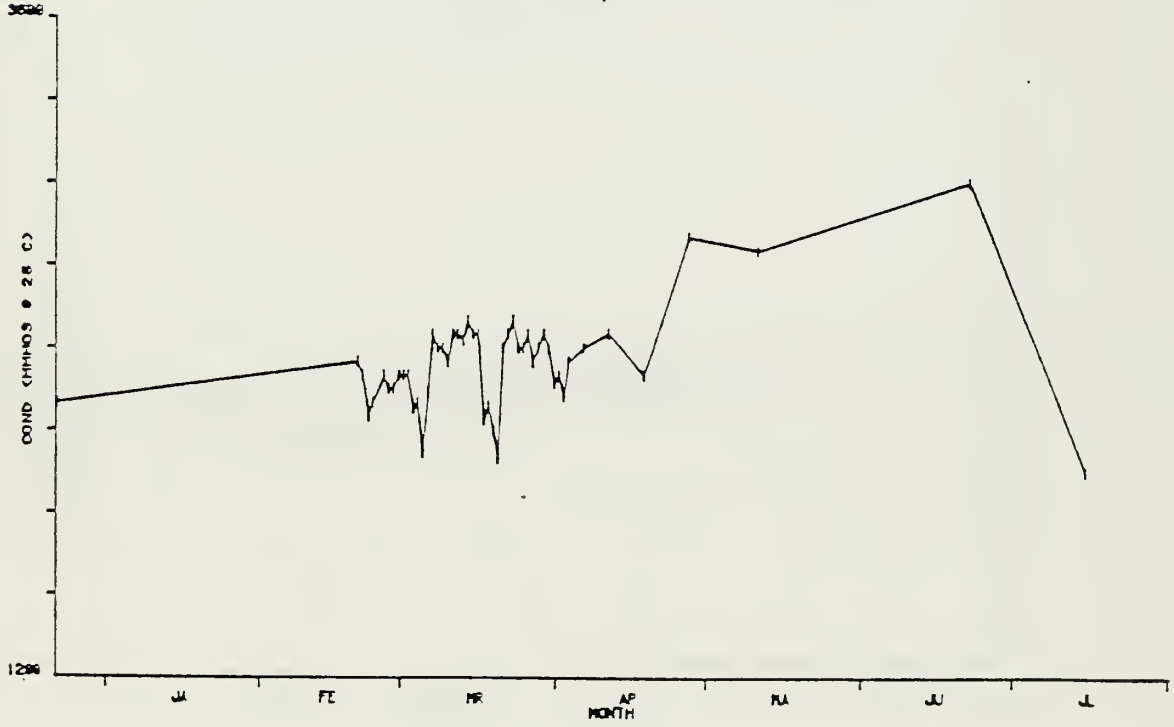


Figure 5-36

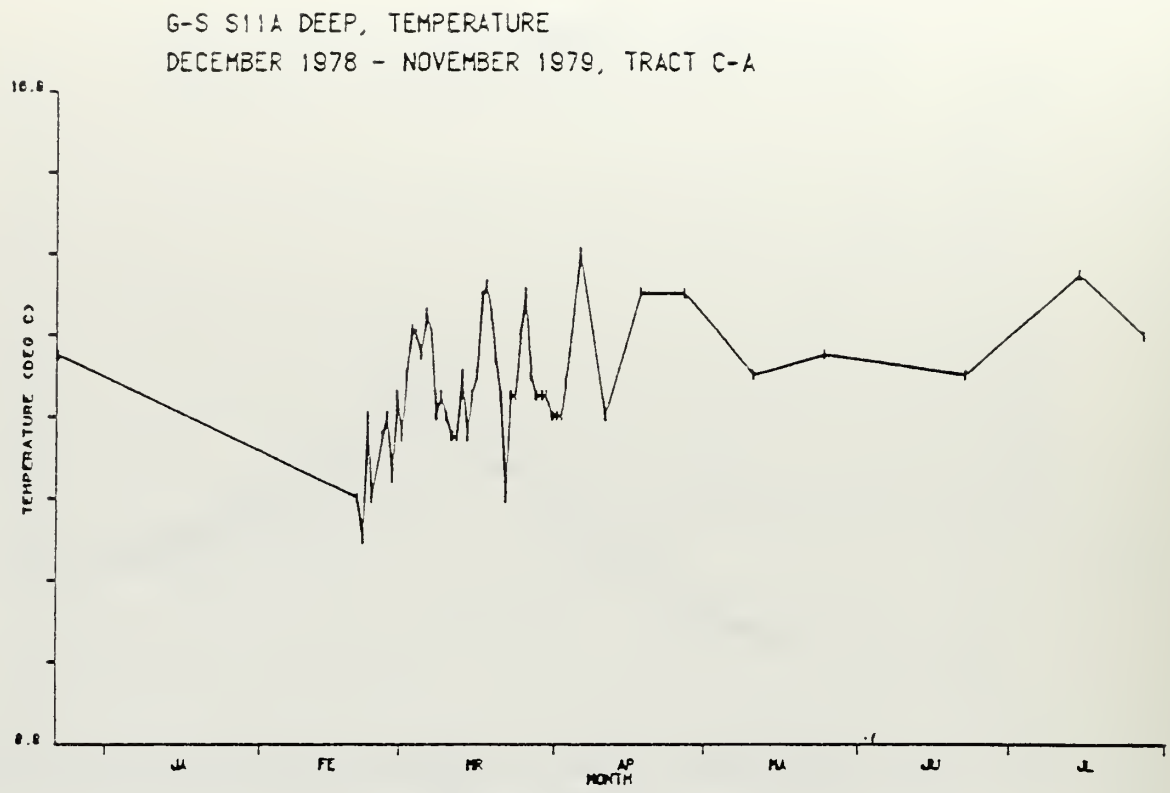


Figure 5-37

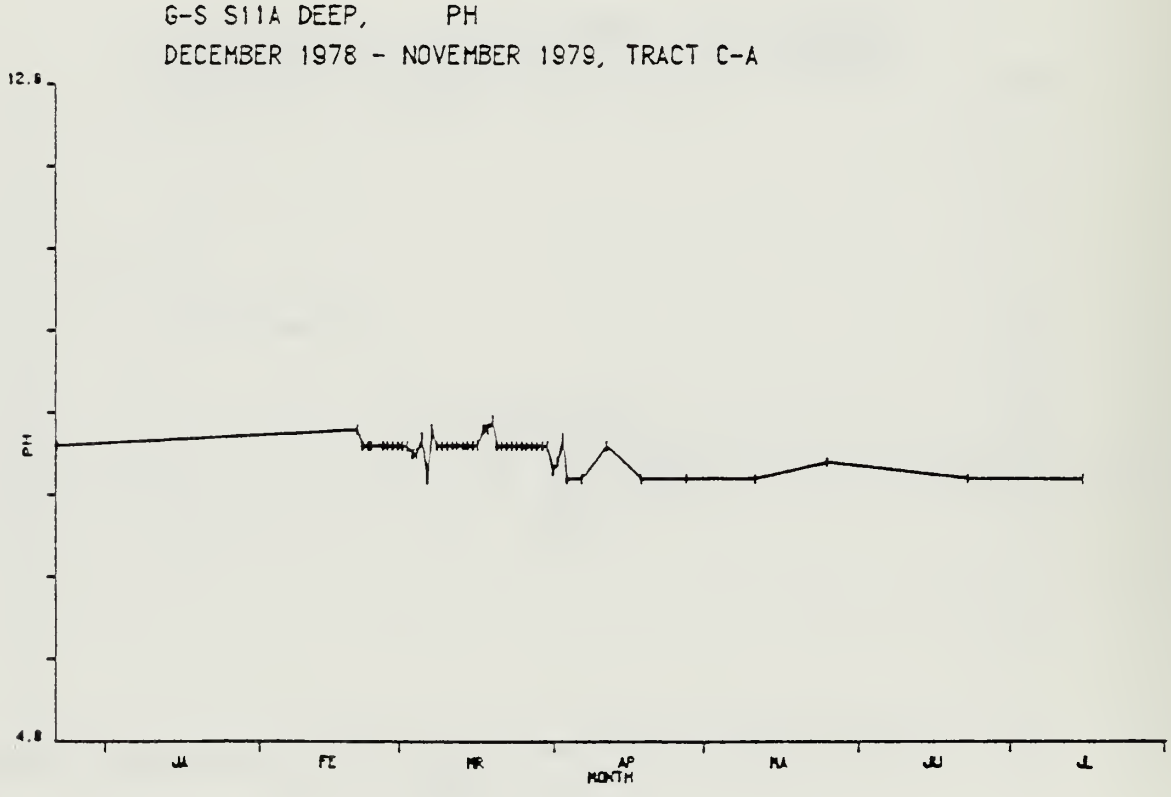


Figure 5-38

G-S S11A SHALLOW, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

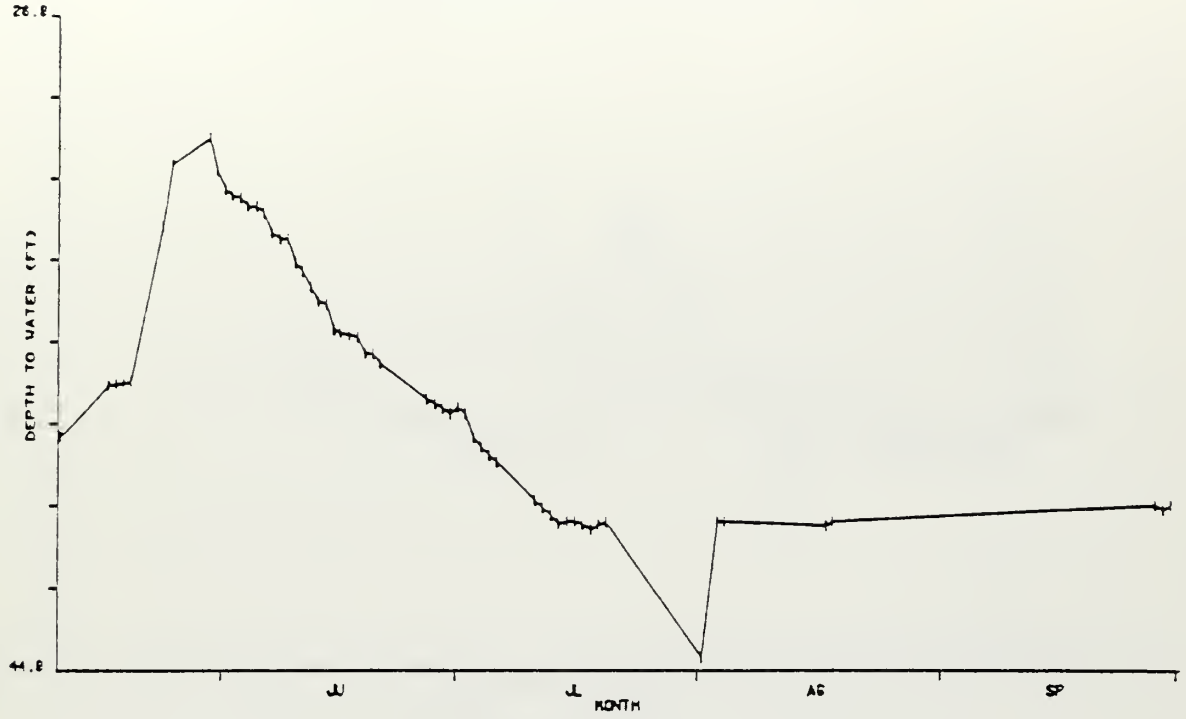


Figure 5-39

G-S S11A SHALLOW, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

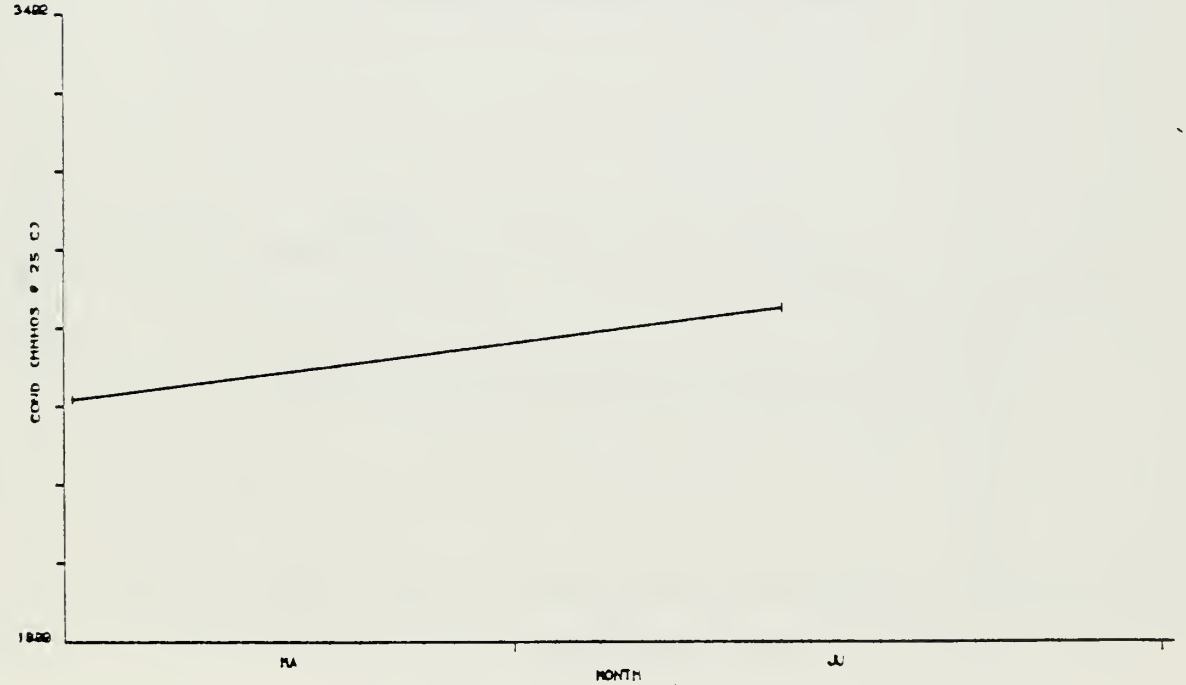


Figure 5-40

G-S S11A SHALLOW, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

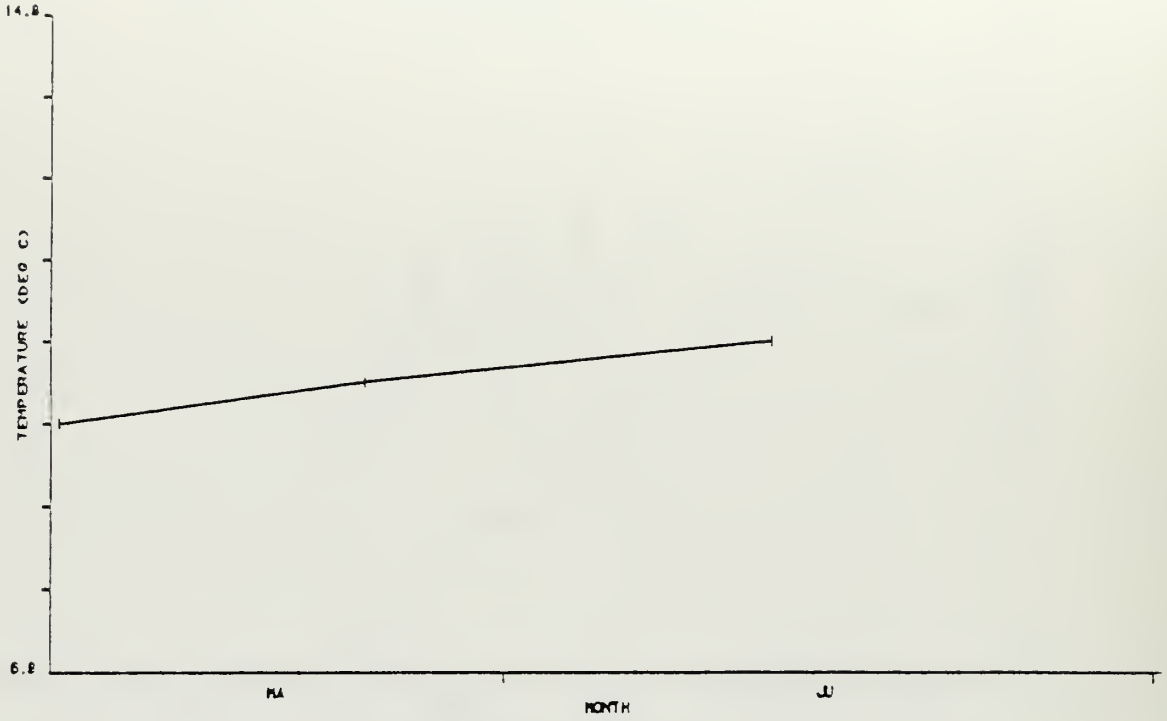


Figure 5-41

G-S S11A SHALLOW, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

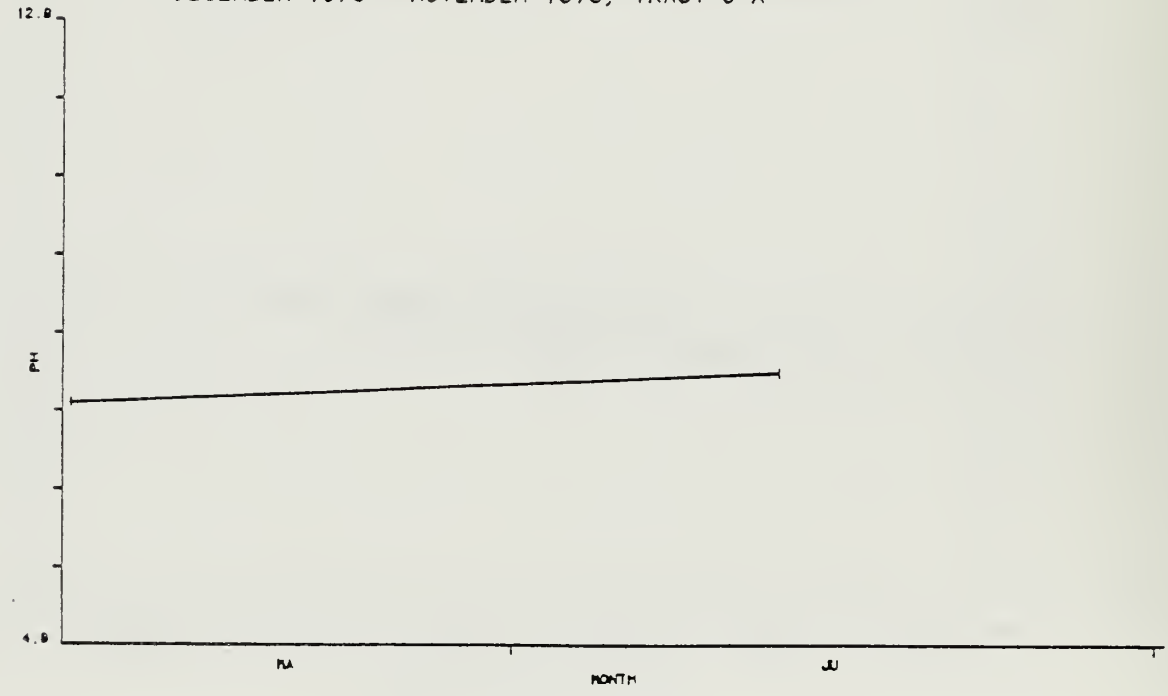


Figure 5-42

G-S S24 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

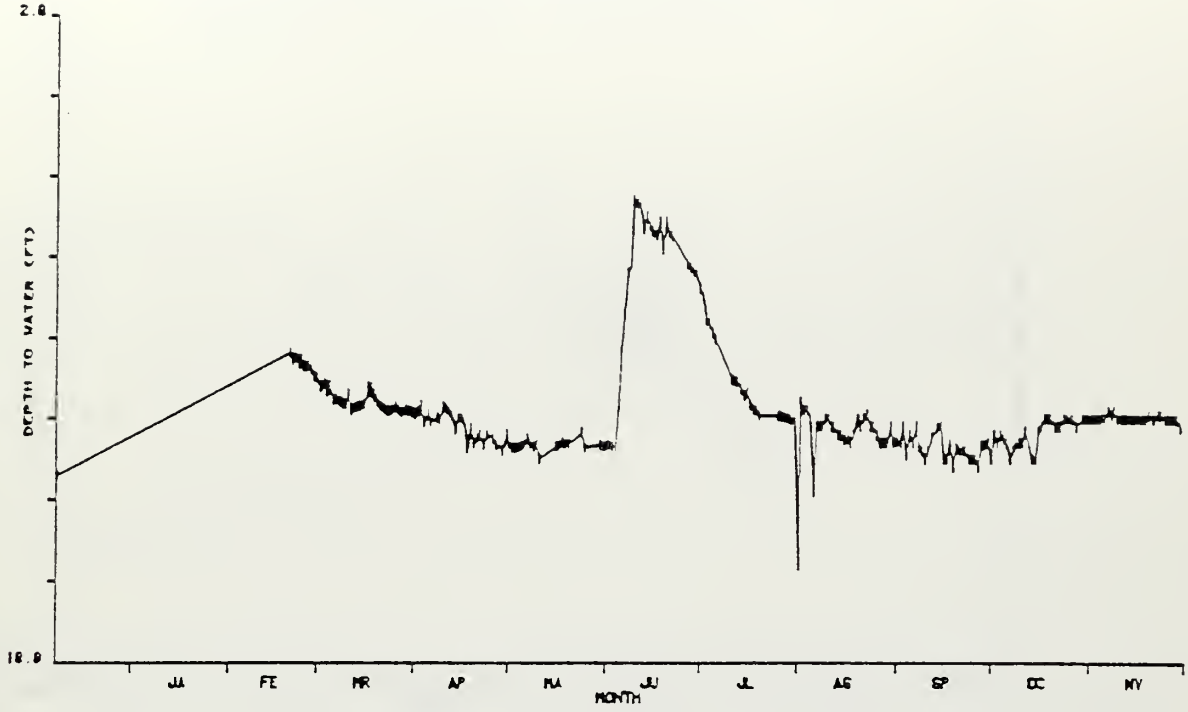


Figure 5-43

G-S S24 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

Figure 5-44

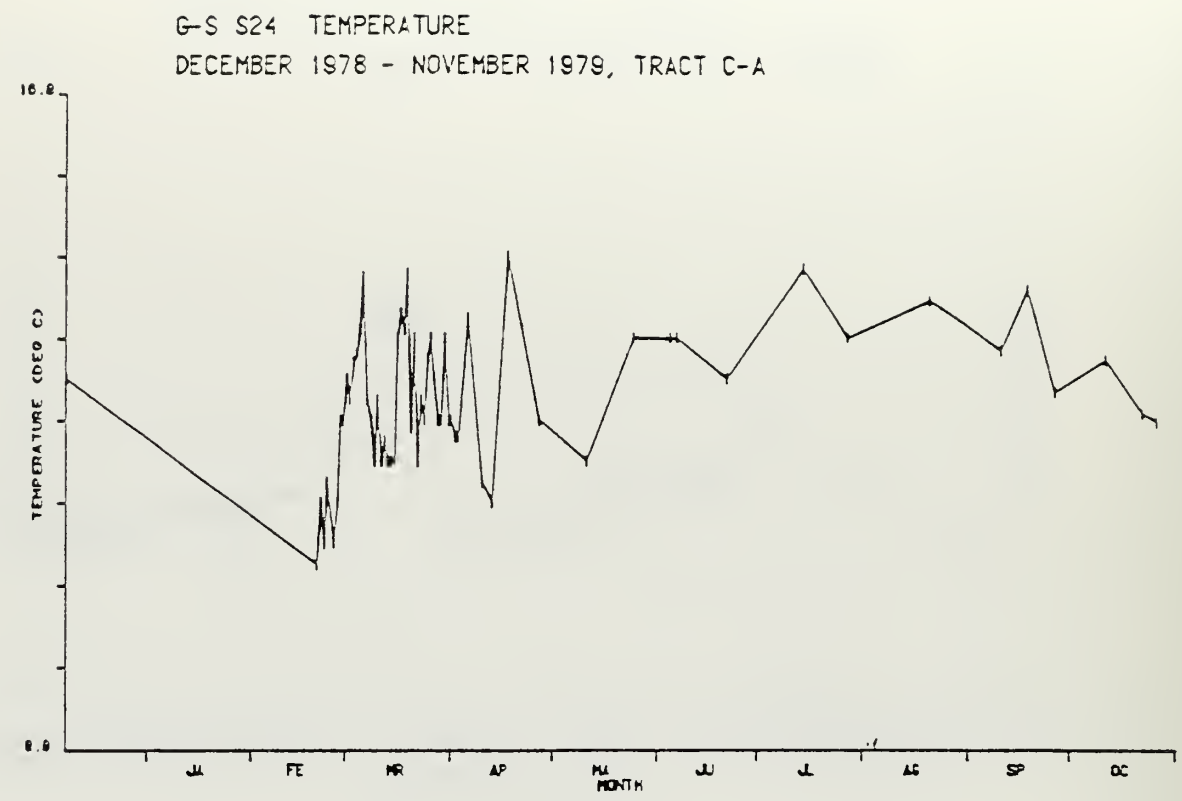


Figure 5-45

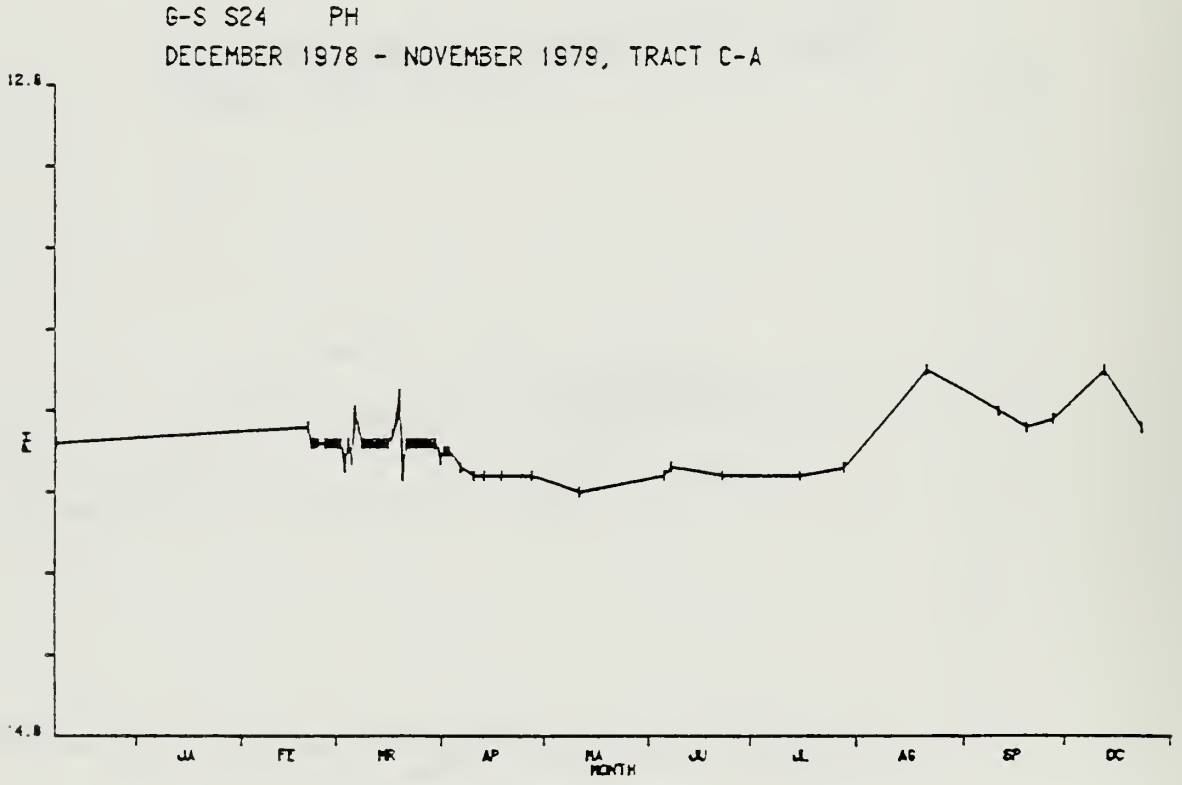


Figure 5-46

G-S S28 SHALLOW, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

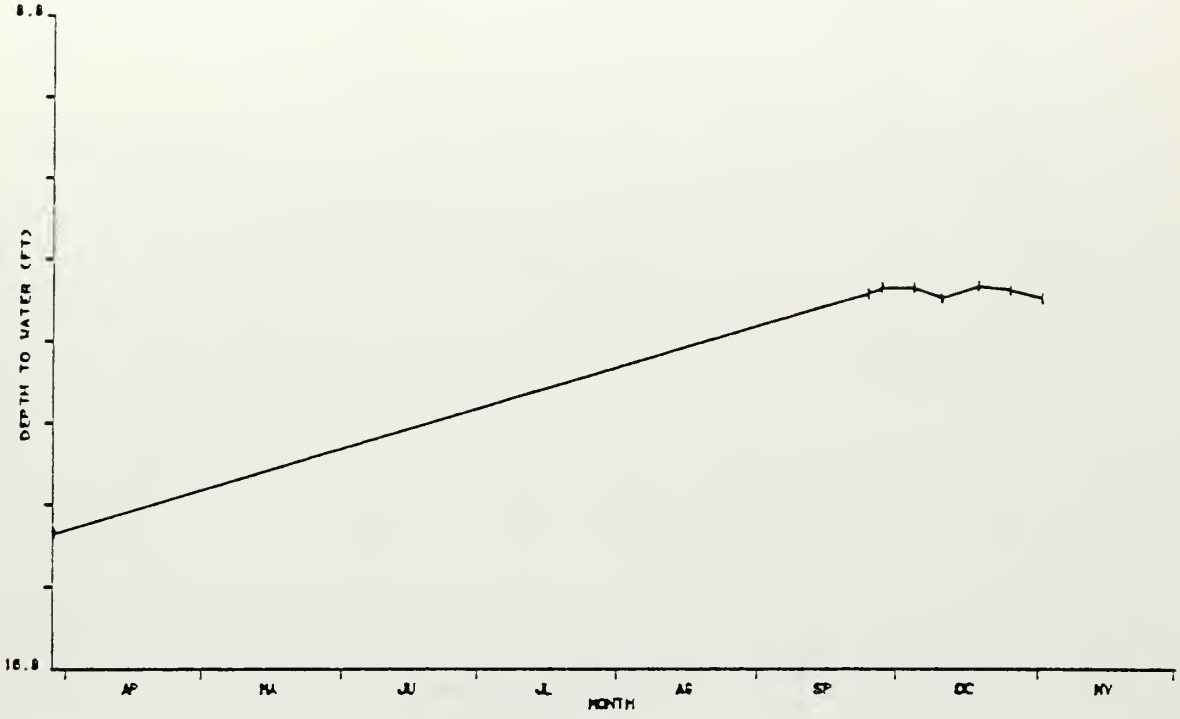


Figure 5-47

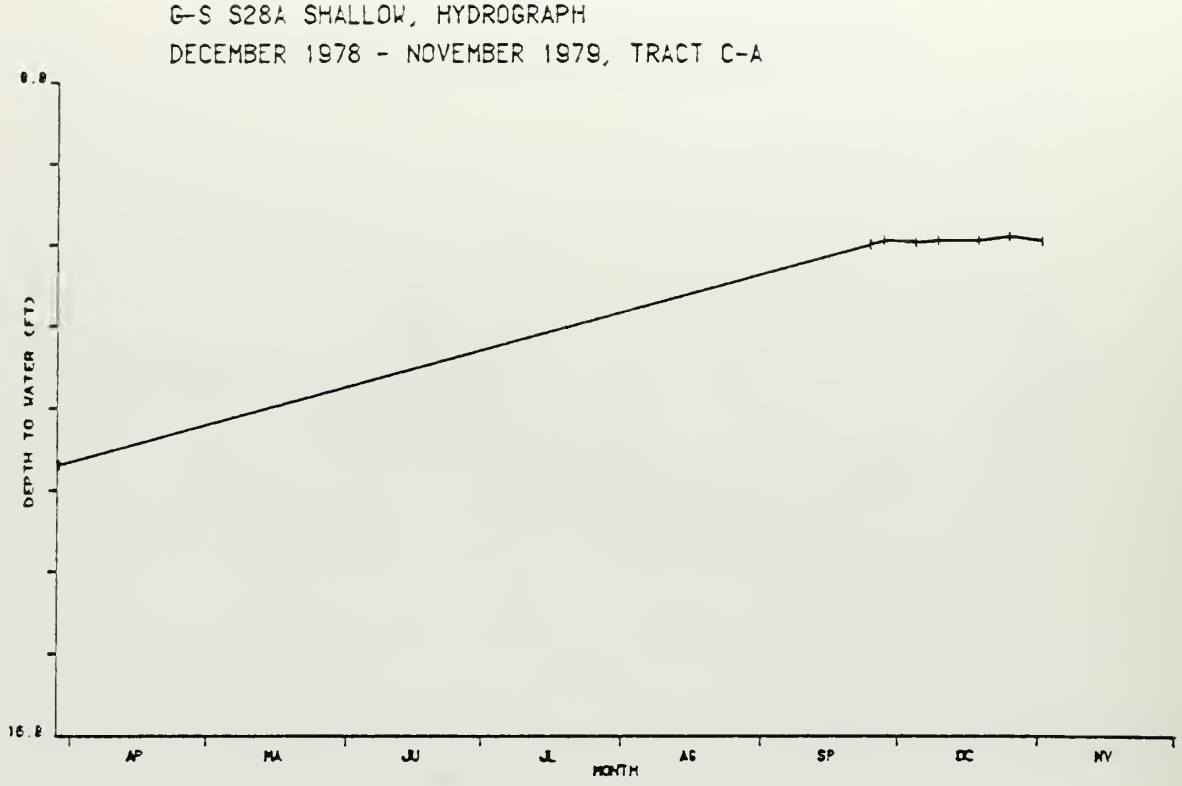

G-S S28A SHALLOW, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A
0.0
DEPTH TO WATER (FT)
16.0
AP
MA
JU
JL
AG
SP
OC
NV
MONTH

Figure 5-48

G-S S28 DEEP, HYDROGRAPH
DECEMBER 1978 - NØVEMBER 1979, TRACT C-A

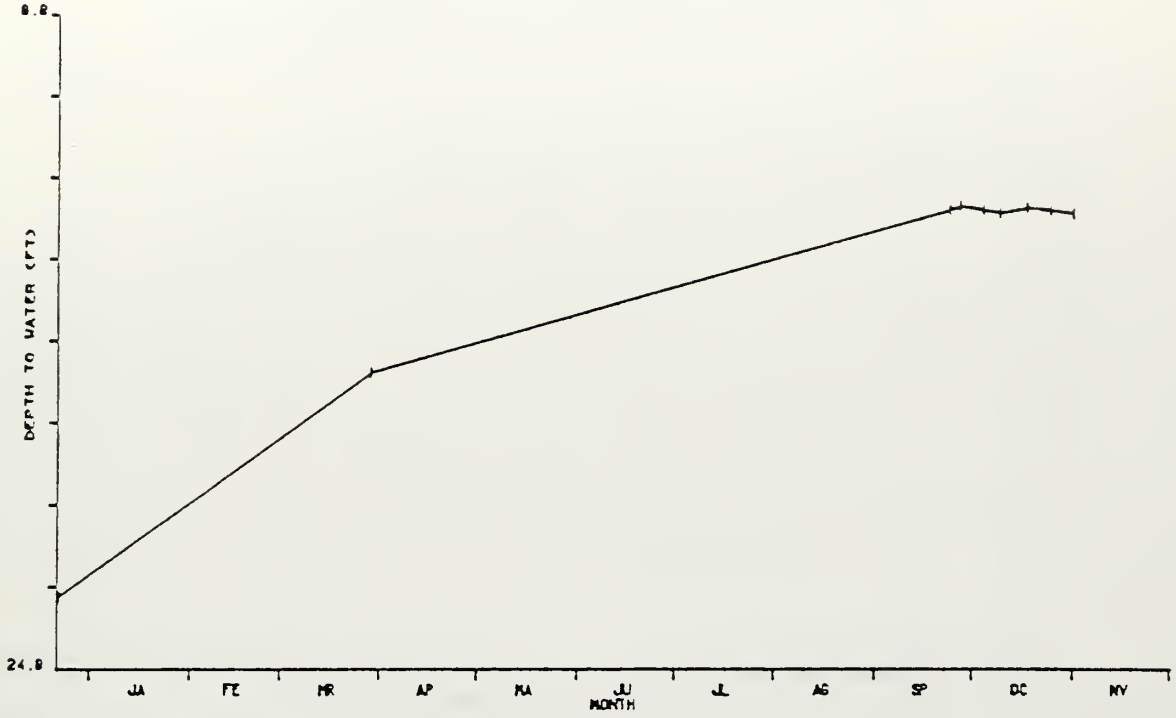


Figure 5-49

G-S S28 DEEP, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

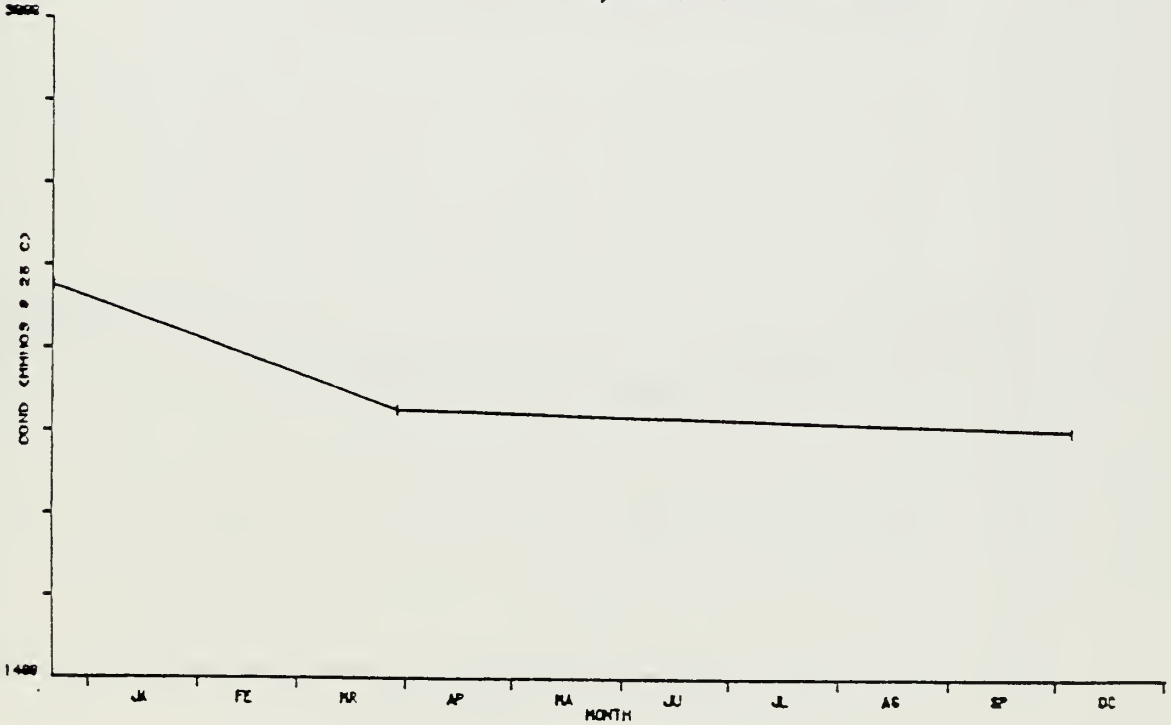


Figure 5-50

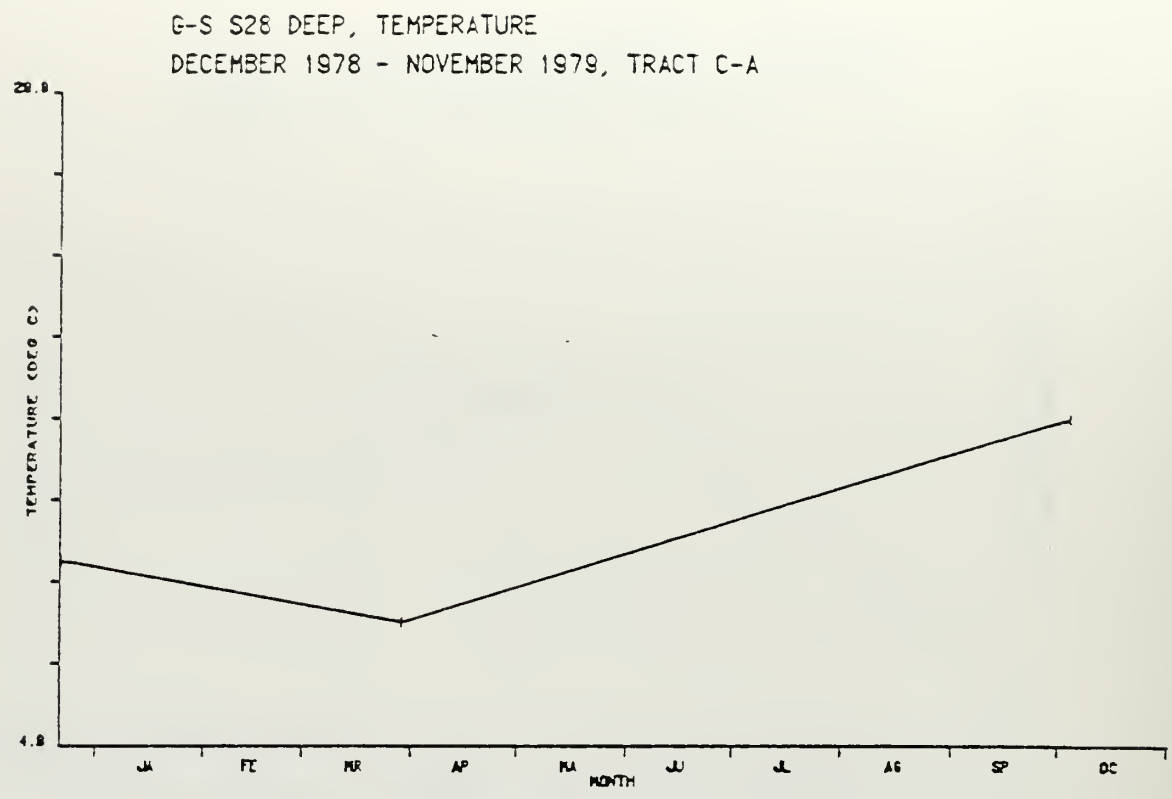


Figure 5-51

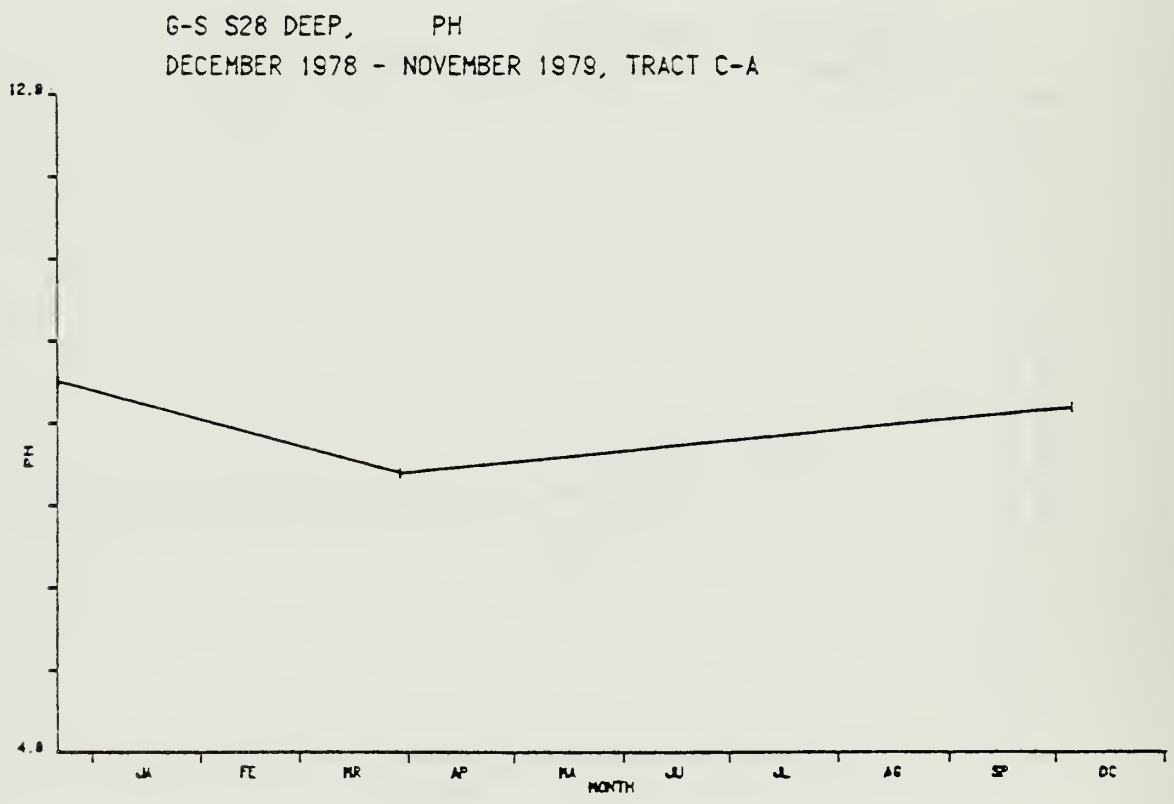


Figure 5-52

G-S S28A DEEP, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

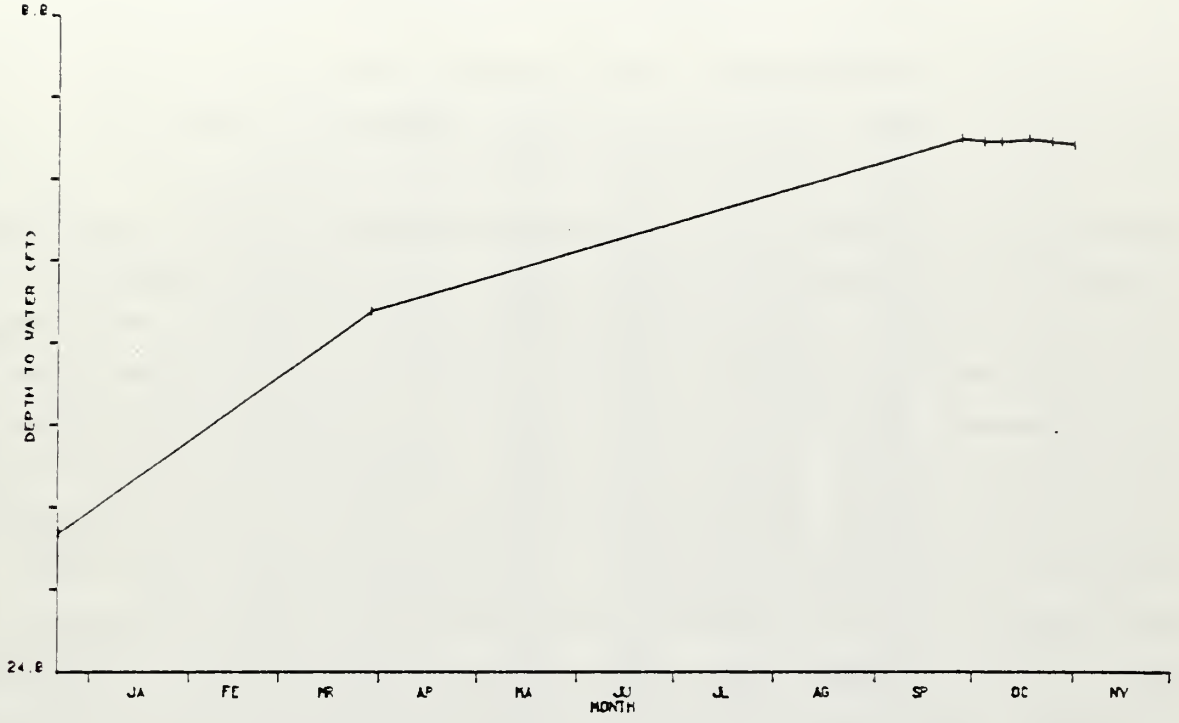


Figure 5-53

b. Chemical parameters - Water quality data collected during the report period December 1978 through November 1979 are presented in Appendix 5-2.1. Summary statistics for individual alluvial wells for the report period are presented in Appendix 5-2.2. A statistical summary of the report period data for the alluvial stations as a group is provided in Table 5-15.

A comparison of baseline with reporting period maximum observed concentrations in Table 5-16 shows that for 13 constituents, maximum levels observed during the baseline alluvial aquifer program were exceeded during the reporting period environmental monitoring program. Several of the increases noted in maximum observed level were relatively small (i.e., chloride, phosphate, potassium and gross beta). With the exception of phosphate and sodium (observed at Wells G-S S7 and G-S S8 respectively), data listed in Table 5-16 were observed at Station G-S S11 (either S11 shallow, S11 deep, or S11A deep). Since Station G-S S11 is located in the Corral Gulch alluvium downstream from Tract C-a, the increased levels observed could possibly reflect the influence of increased water levels in the alluvium and dissolving solids left from evapotranspiration.

As a result of statistical testing of equality of mean concentrations between baseline and reporting period data (described in Section 5.1.A.3.6.), it was determined that statistically significant differences in mean concentration for several constituents exist between the report period and baseline (Table 5-17, Appendix 5-2.2). The higher values of specific conductance and total dissolved solids levels are associated with increased concentrations of alkalinity, sodium, calcium, magnesium, bicarbonate, sulfate, and chloride at Wells G-S S11 and G-S S27, both of which show the influence of mine dewatering discharges during the reporting period.

Specific conductance and several major inorganic constituents were decreased at Well G-S S8, located upstream from the influence of present development activities.

STATION: '79 Alluvial Aquifers . 36 samplings

Parameter	Obs.	Min	Max	Mean	St Dev	95% Conf Inter		Traces
ALUMINUM	7	0.100	0.400	0.172	1.689	0.055	0.269	3
AMMONIA	6	0.280	0.700	0.382	1.413	0.205	0.713	2
ARSENIC	7	0.010	0.010	0.010	1.000	0.010	0.010	7
BICARBONATE	27	384.000	892.000	534.020	1.235	476.004	599.006	0
CADMIUM	7	0.010	0.010	0.010	1.000	0.010	0.010	7
CALCIUM	35	32.000	248.000	97.861	1.550	79.692	120.173	0
CARBONATE	23	0.100	15.600	0.125	2.066	0.046	0.235	22
CHLORIDE	35	9.000	45.500	19.542	1.596	15.696	24.330	0
CHROMIUM	7	0.010	0.010	0.010	1.000	0.010	0.010	7
COPPER	0	0.000	0.000	0.000	0.000	0.000	0.000	0
FLUORIDE	33	0.100	0.500	0.250	1.638	0.196	0.317	1
HYDROXIDE	0	0.000	0.000	0.000	0.000	0.000	0.000	0
IRON	14	0.030	0.500	0.081	2.467	0.033	0.171	10
LEAD	7	0.010	0.030	0.014	1.589	0.007	0.029	3
MAGNESIUM	35	29.000	206.000	77.738	1.798	59.053	102.335	0
MERCURY	7	0.001	0.001	0.001	1.000	0.001	0.001	7
NITRATE	17	0.037	113.000	2.699	7.737	0.606	12.024	0
PHOSPHATE	7	0.100	0.200	0.110	1.300	0.074	0.164	6
POTASSIUM	23	1.000	16.000	3.088	1.889	2.107	4.526	0
SELENIUM	7	0.010	0.010	0.010	1.000	0.010	0.010	7
SILICON DIOXIDE	35	2.900	38.000	18.828	1.645	14.910	23.774	0
SODIUM	35	55.000	1380.000	149.613	1.601	120.025	186.496	0
SULFATE	35	61.000	1590.000	411.227	1.973	299.092	565.401	0
SULFIDE	6	0.200	0.400	0.224	1.327	0.135	0.374	4
ZINC	7	0.040	0.700	0.412	2.823	0.086	1.981	0
RADIO. GROSS ALPHA	5	2.500	25.000	8.276	2.321	1.191	57.490	0
RADIO. GROSS BETA	1	37.000	37.000	37.000	0.000	0.000	0.000	0
HARDNESS, TOTAL	3	550.000	900.000	721.894	1.284	124.686	4179.544	0
PH	25	7.000	8.000	7.476	0.271	7.321	7.631	0
CONDUCTANCE, SPEC.	22	1000.000	3125.000	644.940	1.423	1323.063	2045.174	0
SOLIDS, TOT. DISS.	7	840.000	2500.000	322.100	1.443	743.022	2352.486	0
MANGANESE	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ALKALINITY	35	255.000	730.000	440.595	1.277	392.920	494.054	0
CYANIDE	6	0.010	0.010	0.010	1.000	0.010	0.010	6
BORON	18	0.100	0.300	0.144	1.521	0.107	0.194	2
BARIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
SILVER	0	0.000	0.000	0.000	0.000	0.000	0.000	0
NICKEL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
LITHIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ORG. CARBON, DISS.	13	0.900	41.000	8.723	2.561	3.340	20.164	0
NITRITE-N	5	0.010	3.000	0.123	13.589	0.000	50.582	2
BROMIDE	7	0.100	0.100	0.100	1.000	0.100	0.100	6
COD	7	1.000	30.000	4.771	3.539	0.705	32.299	0
PHENOLS	6	0.001	0.001	0.001	1.000	0.001	0.001	5
KJELDAHL N	0	0.000	0.000	0.000	0.000	0.000	0.000	0
BERYLLIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
MOLYBDENUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
STRONTIUM	7	0.600	3.500	1.487	1.762	0.631	3.503	0
VANADIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
PHOSPHATE, ORTHO	0	0.000	0.000	0.000	0.000	0.000	0.000	0
NITROGEN, AMMONIA	1	0.300	0.300	0.300	0.000	0.000	0.000	1
TEMPERATURE	32	5.000	11.000	8.809	1.778	7.933	9.686	0
H2S	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, TOTAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, FECAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0

Table 5-15. Statistical Summary of Reporting Period Data

Table 5-16. Water Quality Constituents for Which the Maximum Observed Concentration for the Report Period Exceeded the Maximum for the Baseline Period, Alluvial Aquifers

Constituent	Maximum Concentration Observed	
	Baseline Period	Report Period
Bicarbonate	680	892
Calcium	210	248
Chloride	41	45.5
Magnesium	145	206
Phosphate	0.1	0.2
Potassium	14	16
Sodium	350	380
Sulfate	720	1590
Gross Beta	35	37[1]
Total Hardness	810	900
pH	7.2	8.0
Specific Conductance	2252	3125
Total Dissolved Solids	1650	2500

Note: [1] Only one observation for report period.

Table 5-17. Results of Testing of Equality of Alluvial Aquifer Baseline and Report Period Mean Concentrations. Constituents Listed are Those for Which the Null Hypothesis of Equality of Means was Rejected

	Station or Stations Compared to Baseline						
Constituent	All Wells[1]	G-S S 7	G-S S 8	G-S S 11AD	G-S S 11D	G-S S 11S	G-S S 27
Sp. Conductance	>[2]		<	>	>	>	>
TDS	>	>					>
pH	>	>	>	>	>	>	>
Alkalinity	>			>	>		>
Total Hardness	>						
Sodium		<		>	>		
Potassium		<	<				
Calcium			<		>		
Magnesium	>		<	>	>		>
Carbonate	<	<	<	<	<		
Bicarbonate	>		<	>	>		>
Sulfate	>		<	>	>		>
Chloride	>	>		>	>		
Nitrate					>		<
Boron		<					
Silicon Dioxide	<	<	<		<		<
Cadmium	<	<			<		<
Iron	<	<		<	<		<
Lead	<	<			<		<
Mercury	<	<			<		<
Zinc					>		
Strontium		<					
COD	<				<		<
DOC	<	<					

[1] Means of all alluvial wells in environmental monitoring program compared to baseline alluvial aquifer mean concentrations.

[2] > and < symbols indicate differences in means of baseline and report period; < indicates that report period mean is less than baseline; > indicates report period mean greater than baseline.

[3] Blank in table indicates that means tested not different (hypothesis of equality of means accepted).

In general, where changes in trace constituents were observed, reporting period means were lower than baseline mean concentrations (Table 5-17). This is shown for cadmium, boron, iron, lead, mercury, and strontium. In addition, levels of organic constituents, as measured by COD and DOC, were significantly lower during the reporting period relative to baseline alluvial aquifer characteristics.

Testing of changes in general water quality composition in the alluvial aquifers is shown in Table 5-18. The Spearman rank-order correlation analysis indicated that the relative levels of major inorganic ions observed during the reporting period were not different from baseline levels.

Table 5-18. Spearman Rank-Order Correlation Analysis Alluvial Aquifer of Baseline and Reporting Period Means of Major Inorganic Ions

Constituent	Baseline Period Mean (mg/l)	Baseline Period Mean (meq/l)*	Baseline Period Rank	Report Period Mean (mg/l)	Report Period Mean (meq/l)*	Report Period Rank
Sodium	151.1	6.57	2	149.6	6.50	3
Calcium	96.4	4.82	4	97.8	4.89	5
Magnesium	57.0	4.67	5	77.7	6.37	4
Potassium	3.7	0.10	7	3.1	0.08	7
Chloride	12.8	0.36	6	19.5	0.55	6
Carbonate	0.3	0.01	8	0.1	0.03	8
Bicarbonate	458.7	7.52	1	534.0	8.75	1
Sulfate	297.0	6.19	3	411.2	8.57	2

Spearman's Coefficient (r_s) = 0.95 **

** Significantly different from 0

$\sum d = 0$: $\sum d^2 = 4$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

B. Deep Oil Shale Aquifers (Upper and Lower)

1. Objectives

Deep (upper and lower) oil shale aquifers are being monitored during the modular development phase for water level and water quality. These data are analyzed and compared with data collected during the baseline period, for the purpose of detecting changes in the aquifer due to oil shale development activities. In addition, the objective of the monitoring program is to determine if lease and permit requirements, and applicable laws and regulations are being met.

2. Methods

a. Upper aquifer holes - Water levels are monitored daily in the upper aquifer in 14 boreholes, and weekly in six other boreholes (see Map 1, Map pocket). Water quality samples are collected monthly at 10 holes and analyzed for pH, conductivity, temperature, alkalinity, and major ions. Quarterly sampling is done in three of these holes for pH, conductivity, temperature, alkalinity, and major constituents. Semi-annual water quality samples are collected in January and July at seven holes and analyzed for all constituents listed in the extensive program (Table 5-3). In addition, annual samples are collected in July at six other upper aquifer holes and are also analyzed for all parameters in the extensive program.

b. Lower aquifer holes - Water levels are measured daily in one hole and weekly in five other holes (see Map 1, Map pocket). Quarterly water quality samples are collected and analyzed for pH, conductivity, temperature, alkalinity, and major constituents. During January and July the water quality samples for the one hole are analyzed for the complete list of constituents presented in Table 5-3. During July the water quality samples for the other five holes are analyzed for the complete list of constituents presented in Table 5-3.

3. Results and Discussion

a. Physical parameters - Because of the change in the scope of work in June of 1979, considerably more data were collected in the second half of the reporting period than in the first half. The physical data which were obtained from the deep oil shale aquifer during this reporting period are presented in alphabetical order for the upper and lower aquifer, respectively.

Lower aquifer wells - The physical data for AM-2A are plotted on Figures 5-54 and 5-55. The hydrograph for this hole indicates little variation of water level, except for a slight decrease near the end of the reporting period in November. Only two temperature measurements were taken, one in June and one in October. The October temperature was between 4 and 5 degrees lower than the June reading, which is normal for groundwater. Data for pH and conductivity were insufficient for constructing graphs for this hole.

Physical data for AM-3 are plotted in Figures 5-56 through 5-59. The hydrograph shows very little variation in water level in December 1978 through May 1979, followed by a rise of roughly six feet between May and July, at which time the levels stabilized for the remainder of the reporting period. This may be a natural seasonal variation, with spring runoff water percolating into the deep aquifer with some time delay. Conductivity showed a decrease between April and October, temperature increased slightly, and pH showed little variation.

Physical data for CE-701 are plotted in Figures 5-60 through 5-63. The hydrograph for this hole is affected by dewatering and reinjection. Conductivity, temperature, and pH all show some variation, but do not indicate any identifiable trends toward change.

AM-2A HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

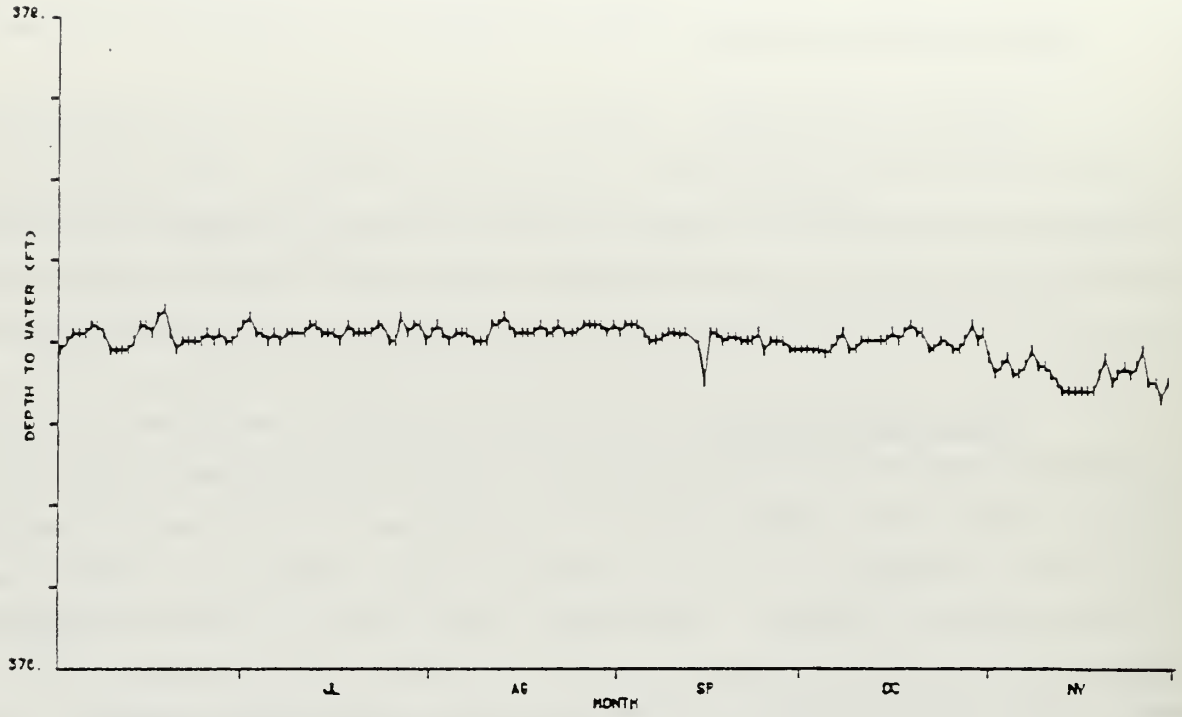


Figure 5-54

AM-2A TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

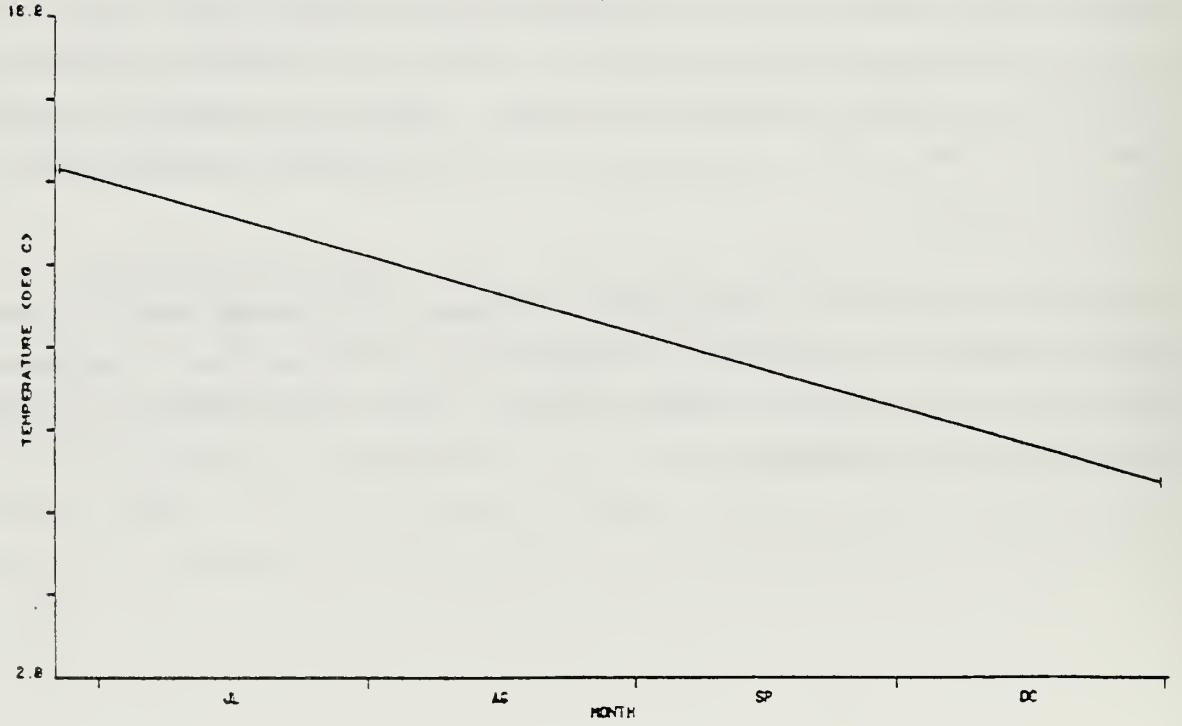


Figure 5-55

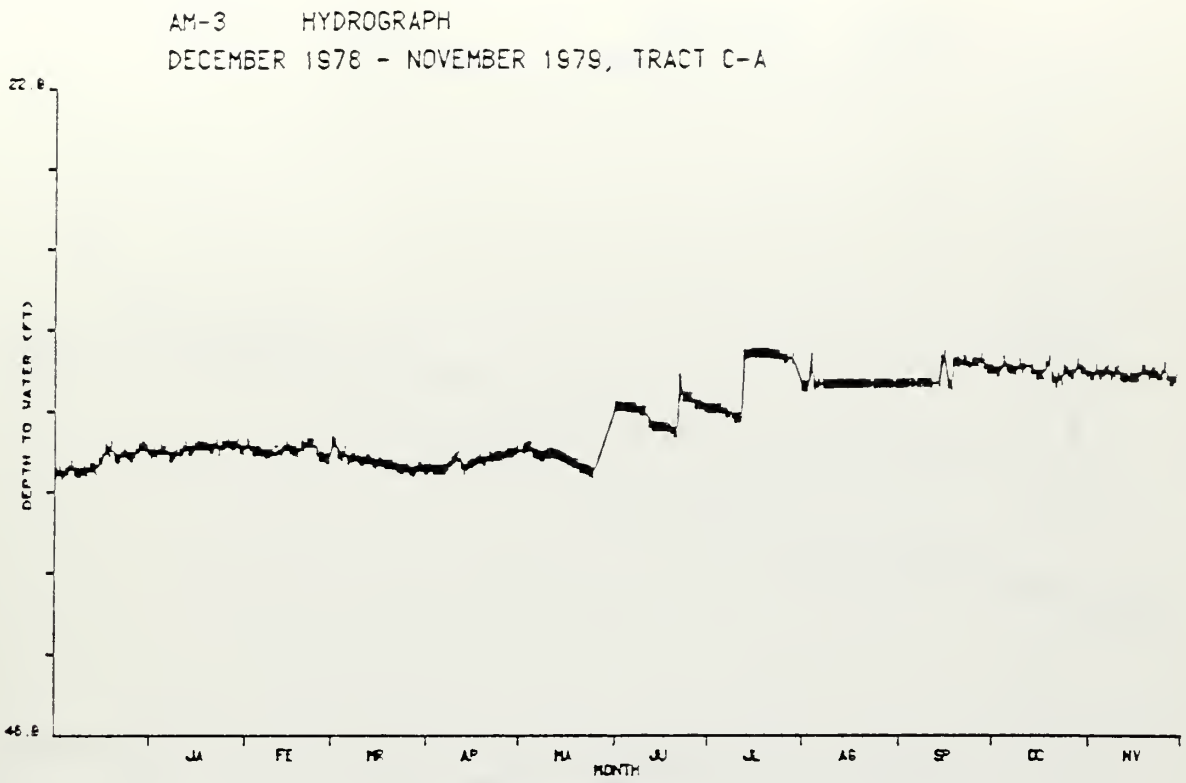


Figure 5-56

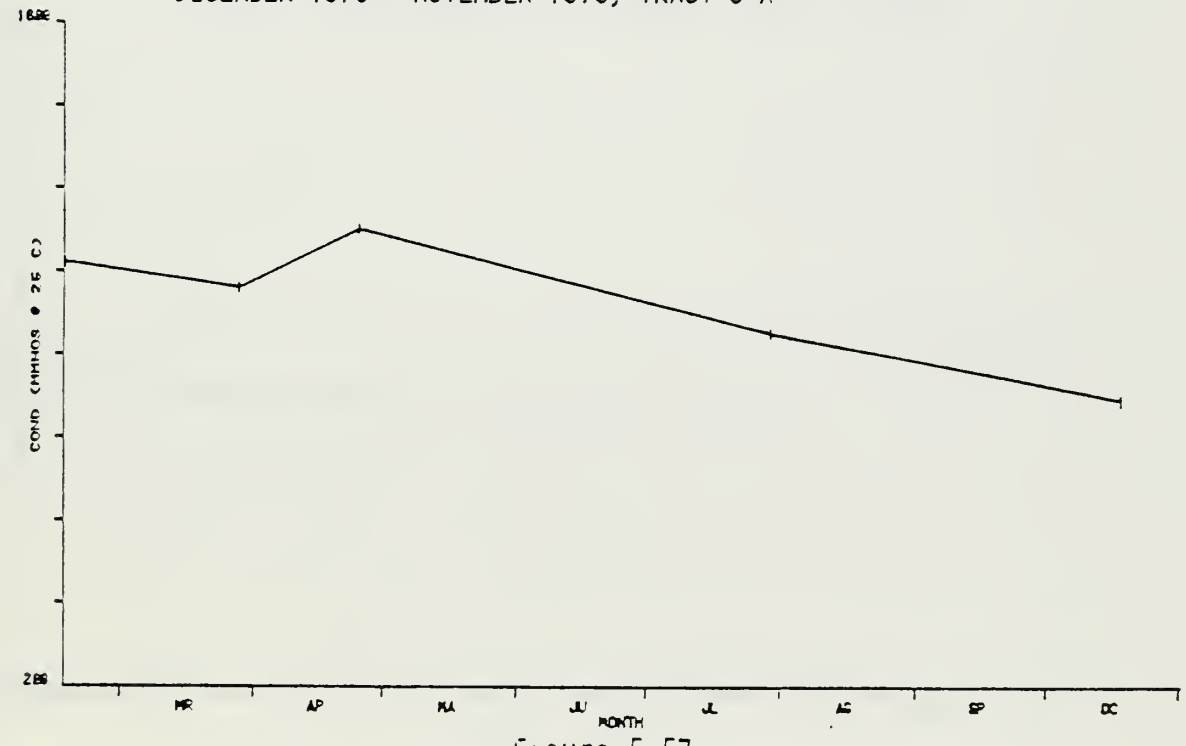


Figure 5-57

AM-3 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

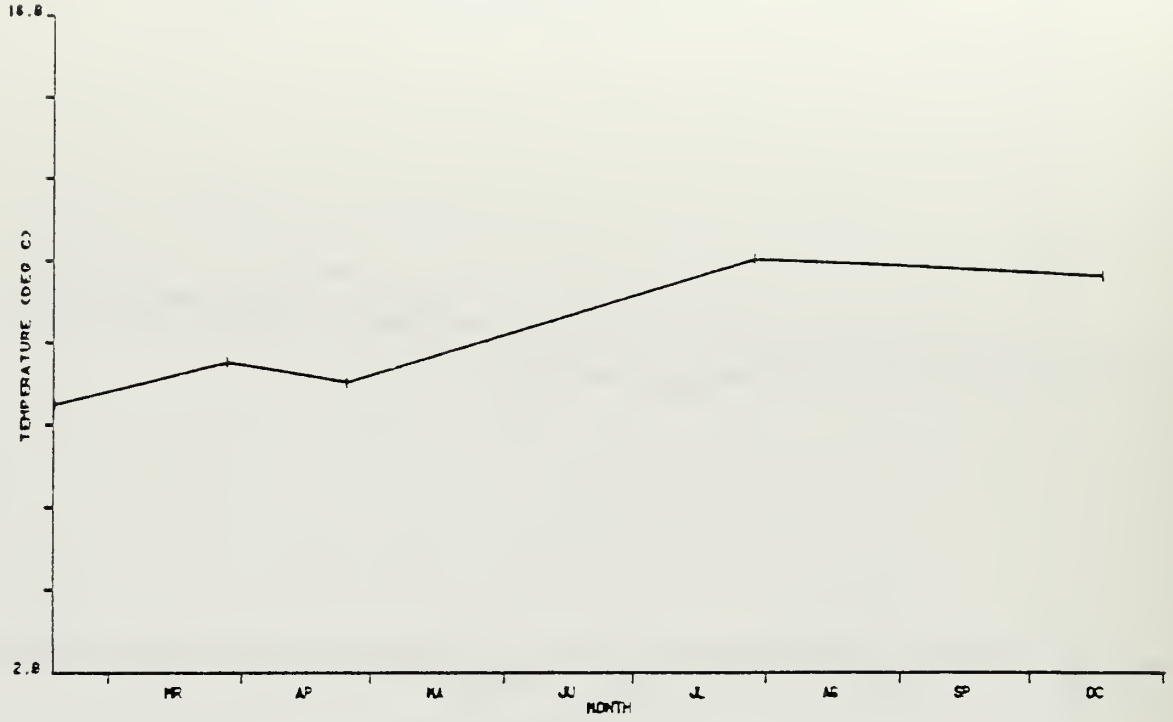


Figure 5-58

AM-3 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

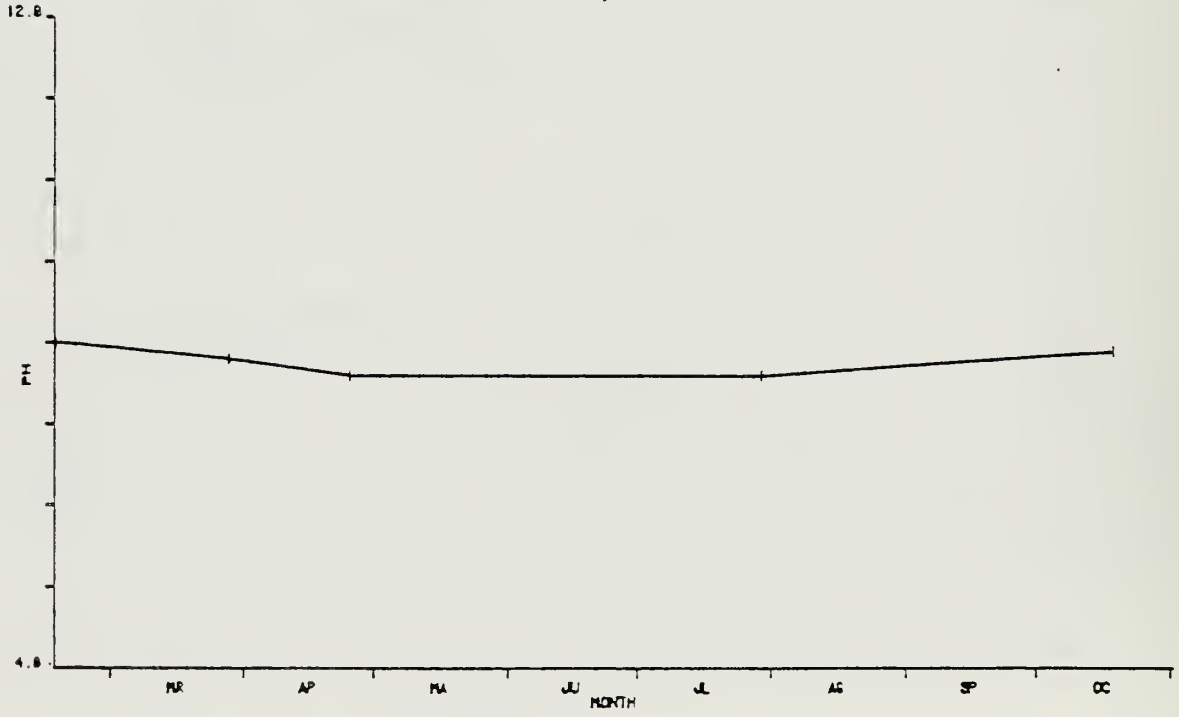


Figure 5-59

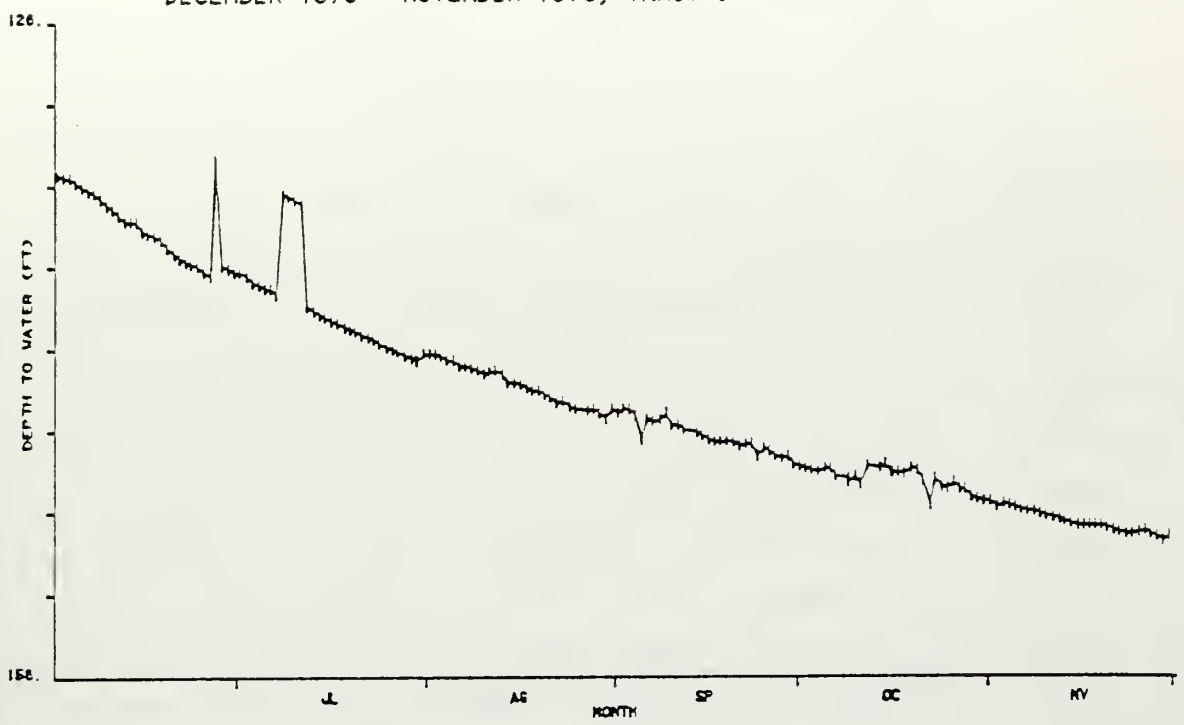


Figure 5-60

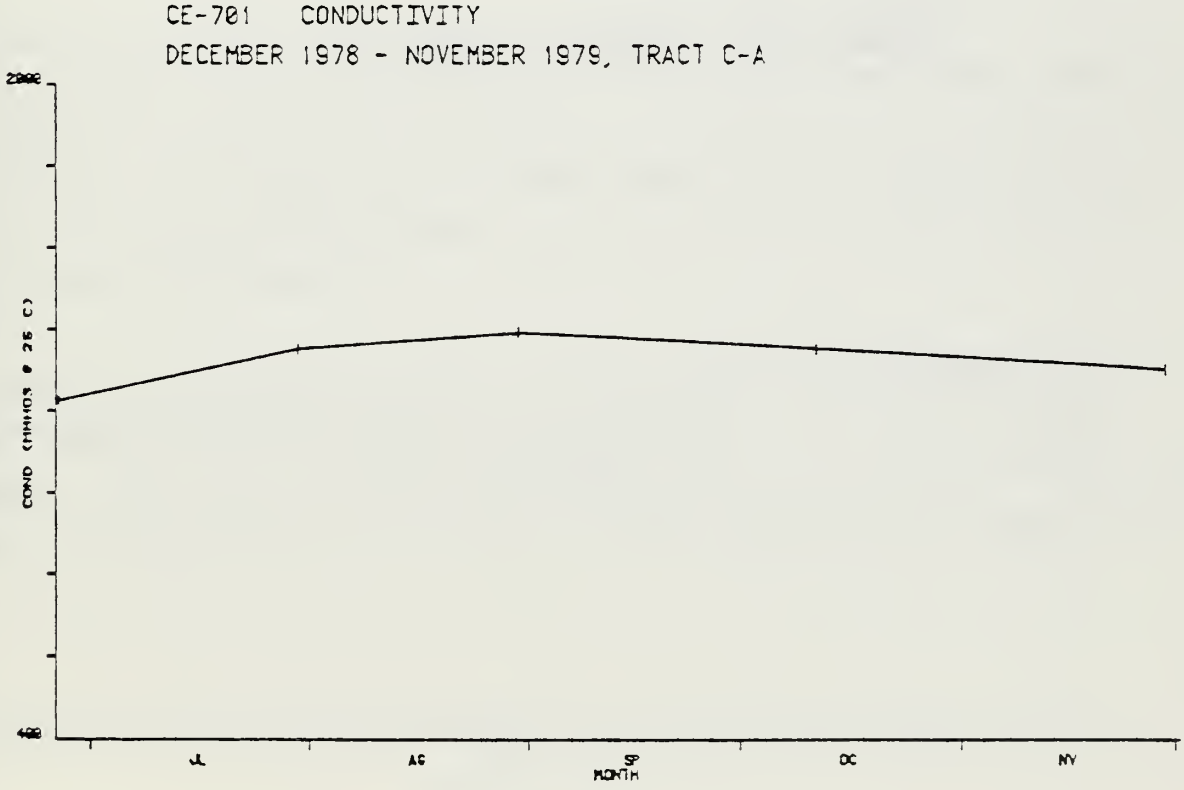


Figure 5-61

CE-701 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

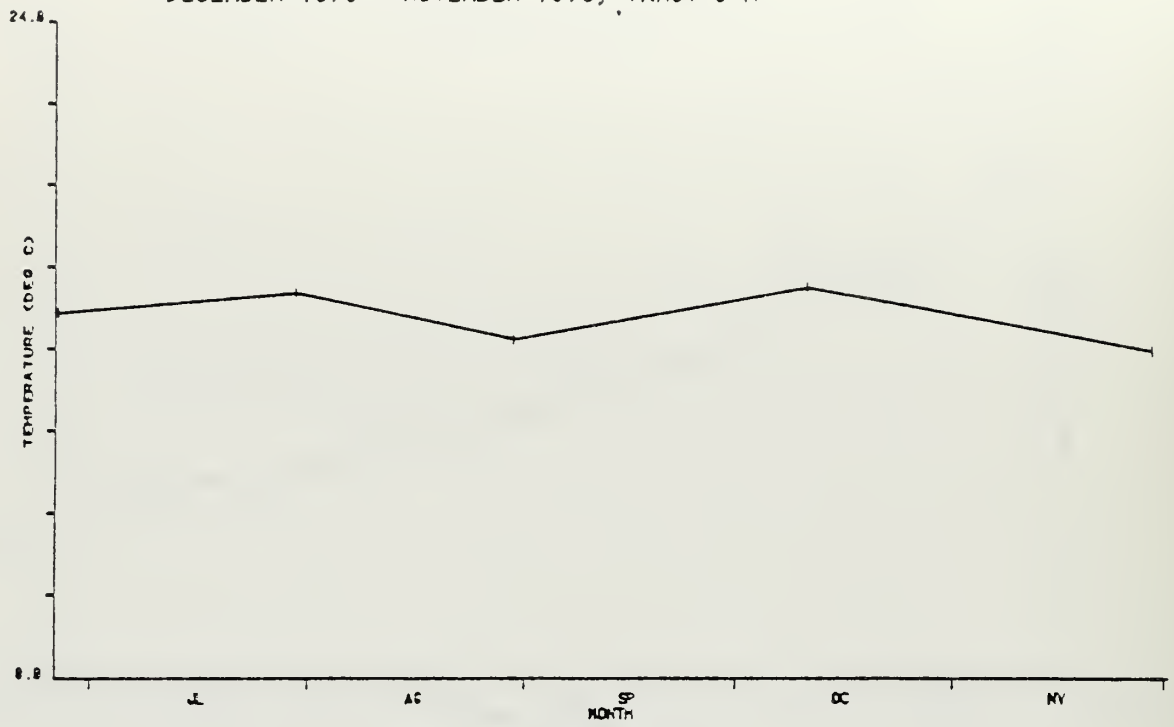


Figure 5-62

CE-701 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

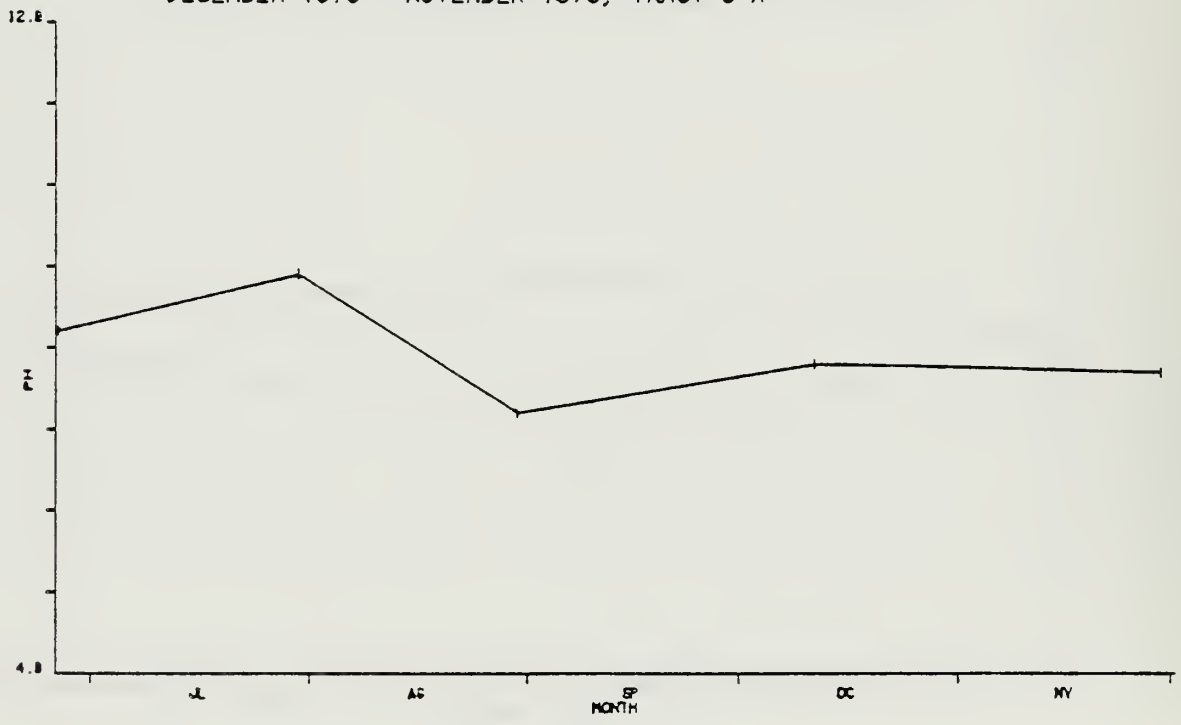


Figure 5-63

Physical data for CE-702 are plotted in Figures 5-64 through 5-67. The hydrograph for this hole indicates that the water levels are affected by dewatering and reinjection. The conductivity plot shows a dramatic rise in conductivity from September to October which is considered to be a bad data point. Other than that, there is no trend in conductivity. The temperature plot for this hole showed a decline in October and November, and there was some fluctuation in pH, but no identifiable trend toward a long-term change.

Physical data for CE-705A are plotted in Figures 5-68 through 5-71. The hydrograph for this hole is affected by dewatering almost exclusively. Short-term variations in water levels during July and August may be due to the impact of recharge to the deep aquifer. The conductivity from July to November declined slightly. The temperature plot indicates a dramatic decrease in temperature in July, which could be a measurement error. Following this decrease, the temperature returns to a higher level, and remains there until October at which time it begins to decline. The plot of pH shows a slight rise near the end of the reporting period.

Physical data for CE-707 are plotted in Figures 5-72 through 5-75. After an initial decline in June, the water levels in this hole remain nearly constant. Measurements of conductivity indicate some fluctuation, but no long-term trend toward change. The temperature plot shows some fluctuation with a declining temperature in October and November, and the pH also shows some fluctuations but no identifiable change.

The hydrograph for CE-708 is shown in Figure 5-76. This hydrograph shows a rise in June, followed by a fairly consistent decline from July through November. This monitoring station is located west of the graben and the fluctuation is apparently due to response to normal recharge of the upper aquifer.

CE-702 UPPER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

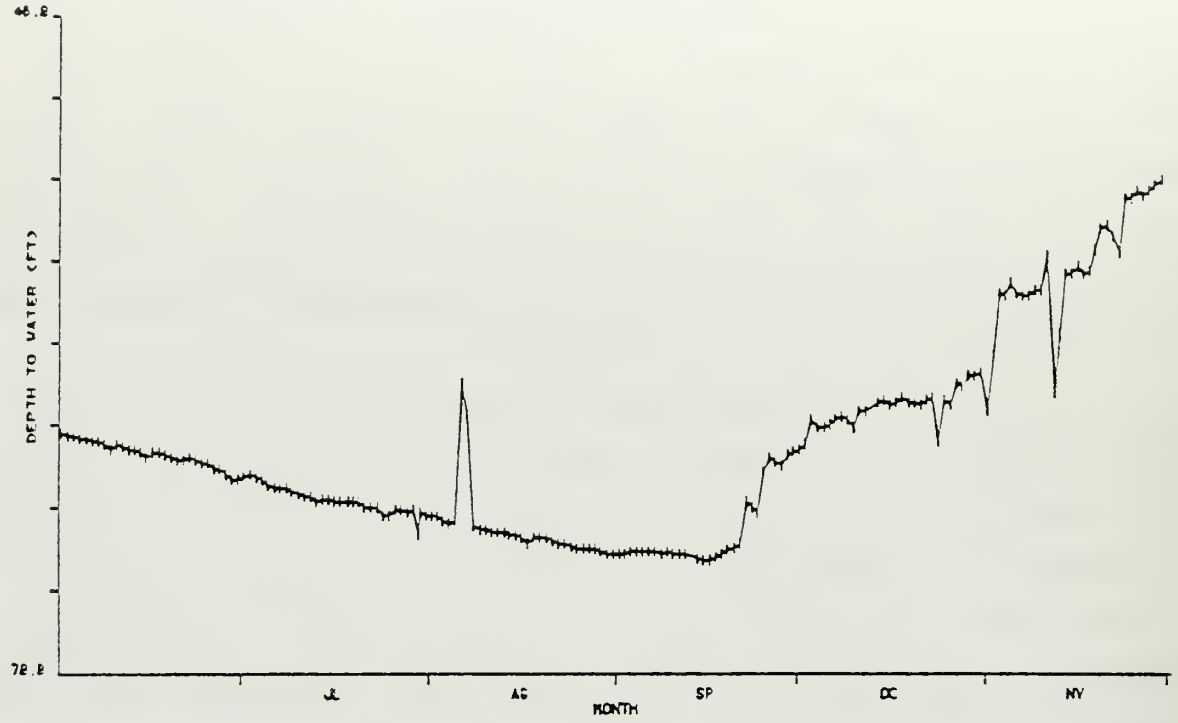


Figure 5-64

CE-702 UPPER, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

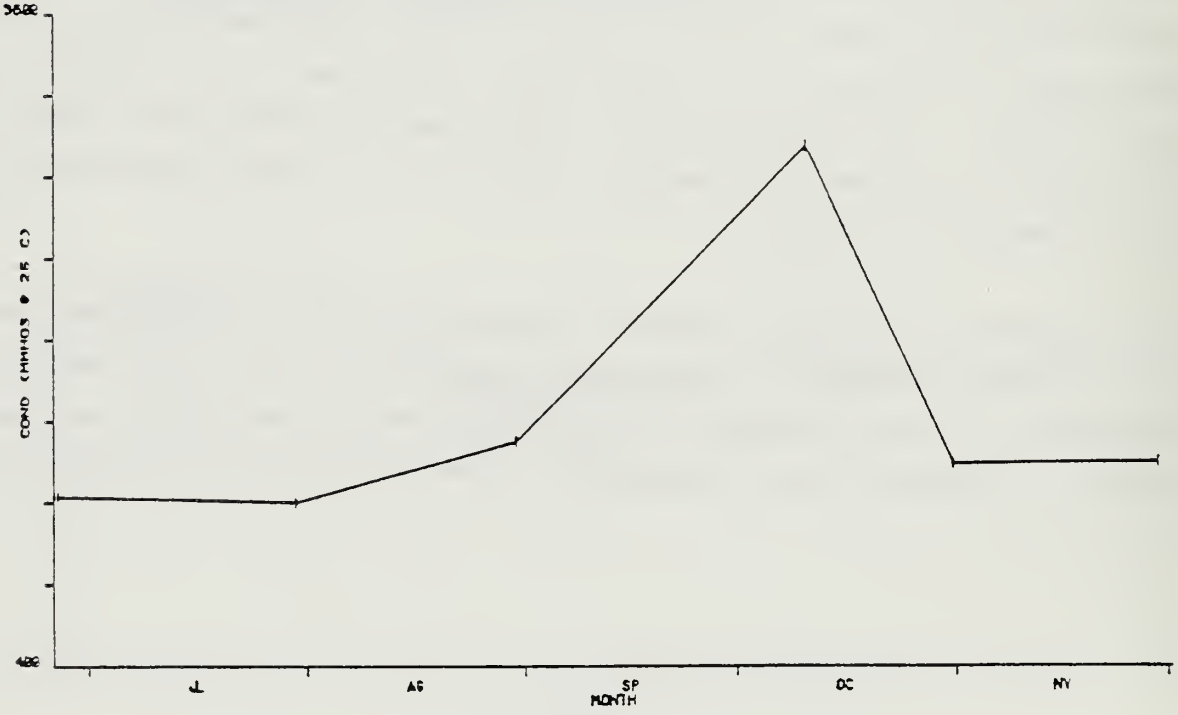


Figure 5-65

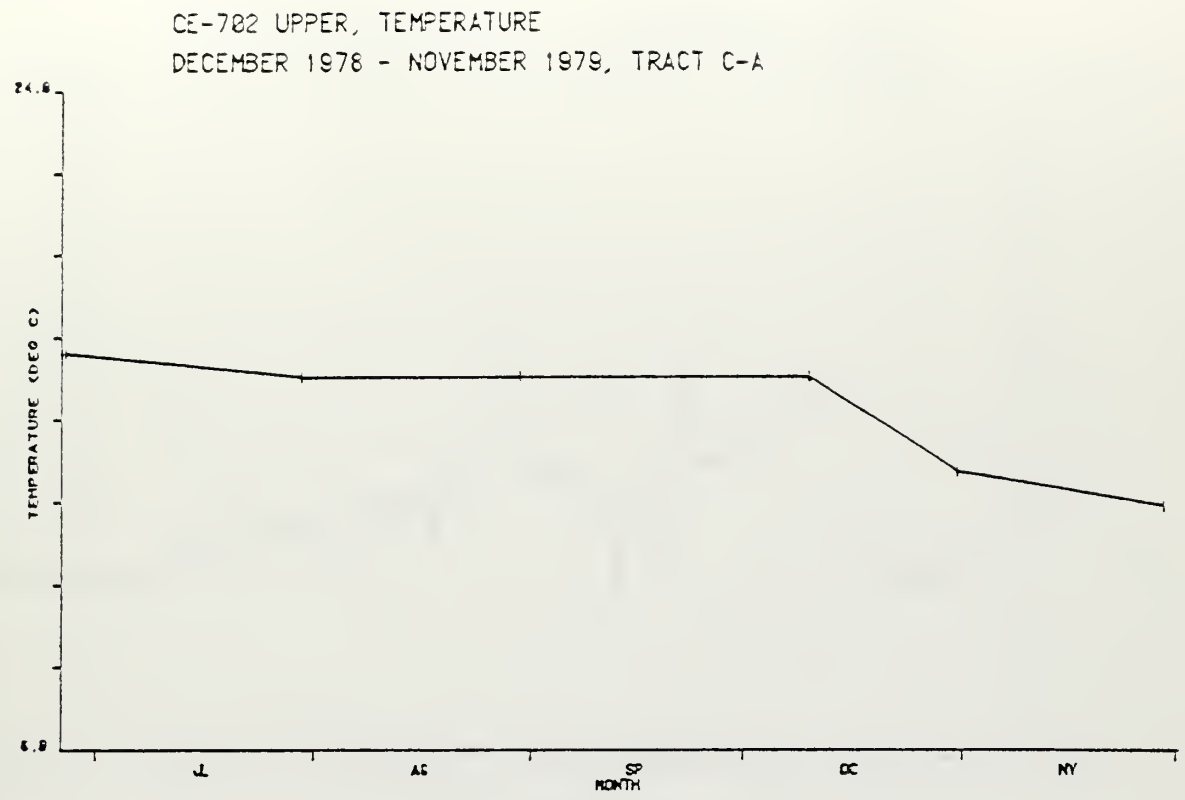


Figure 5-66

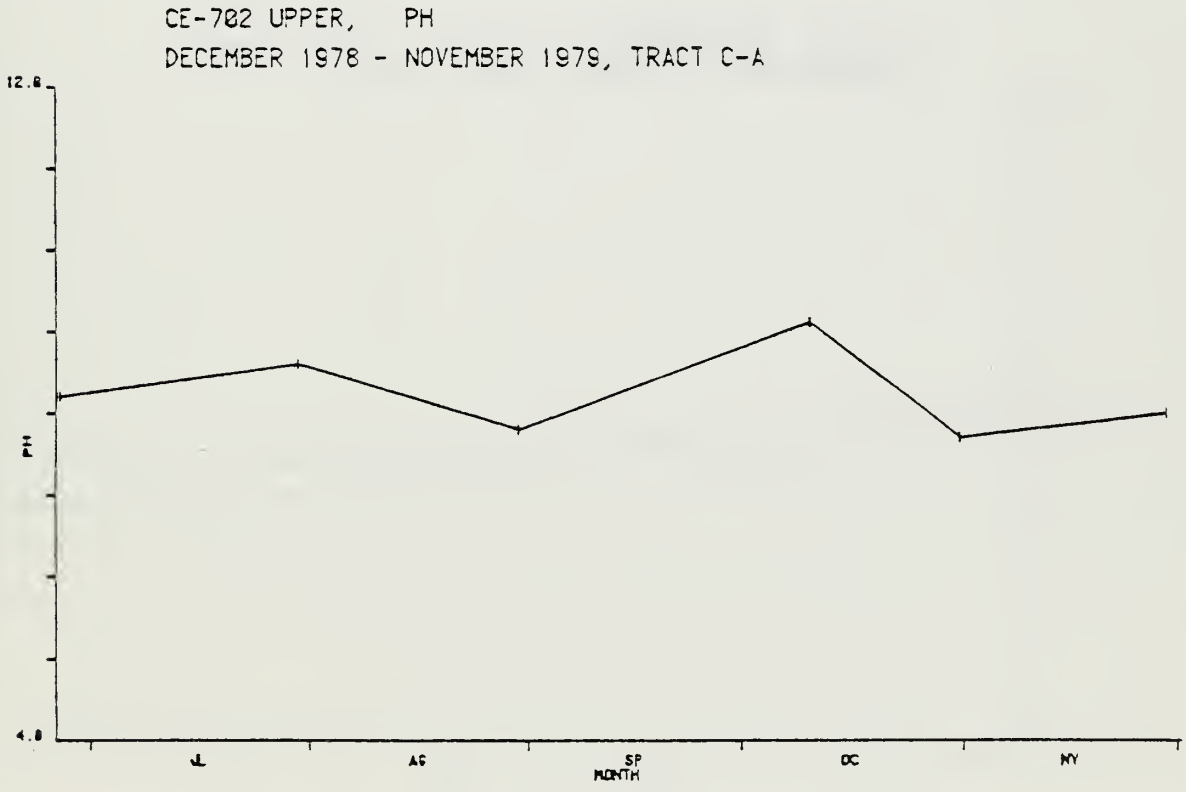
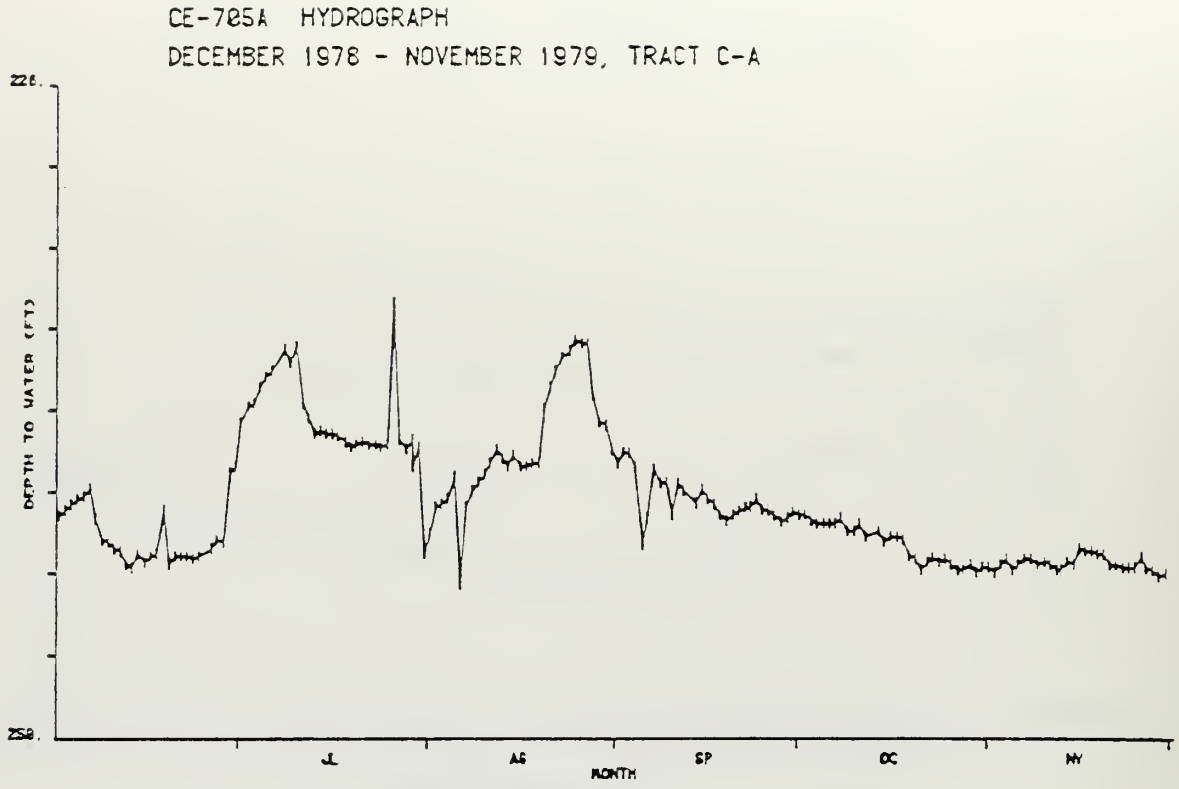


Figure 5-67



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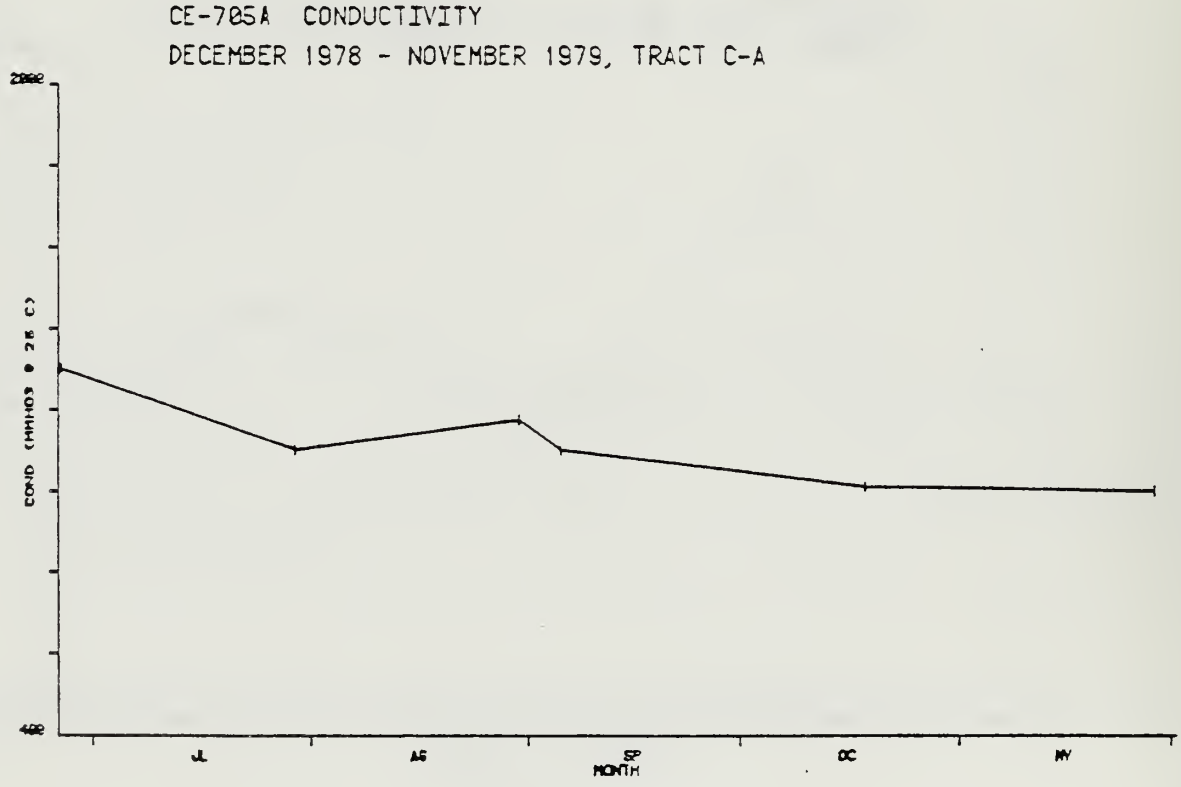


Figure 5-69

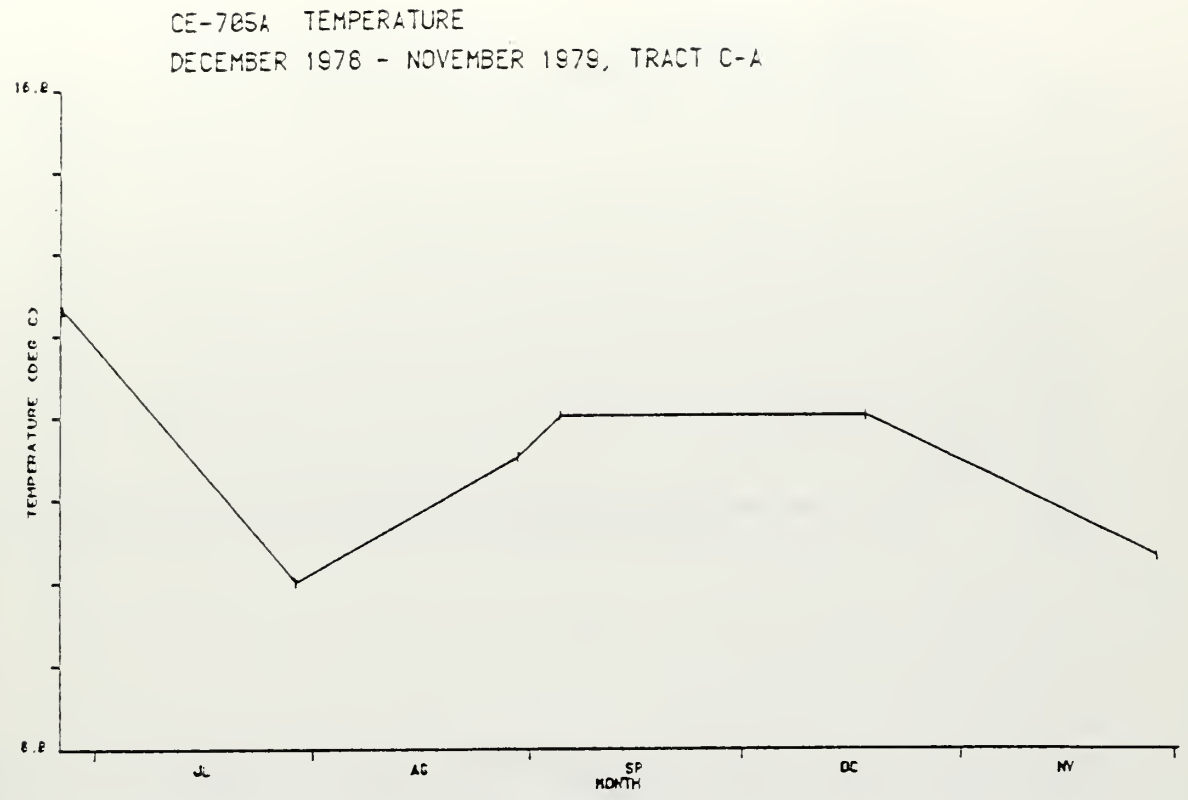


Figure 5-70

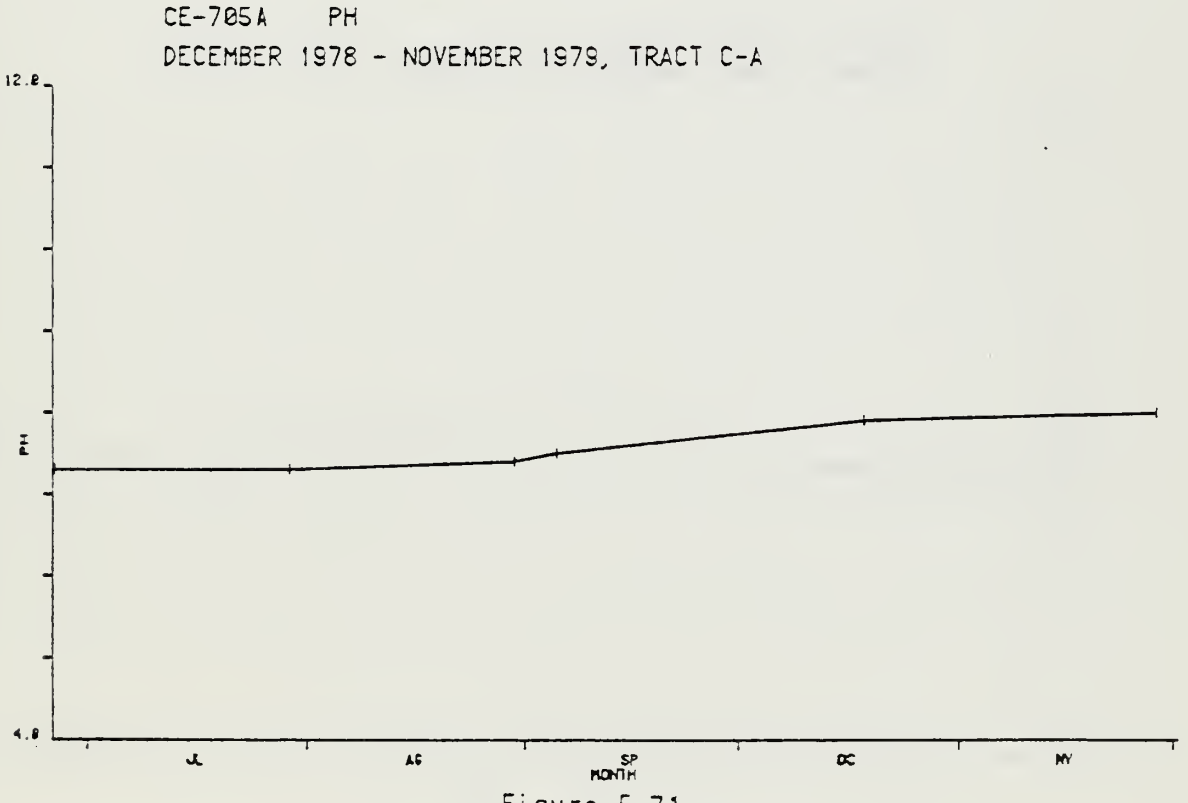


Figure 5-71

CE-707 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

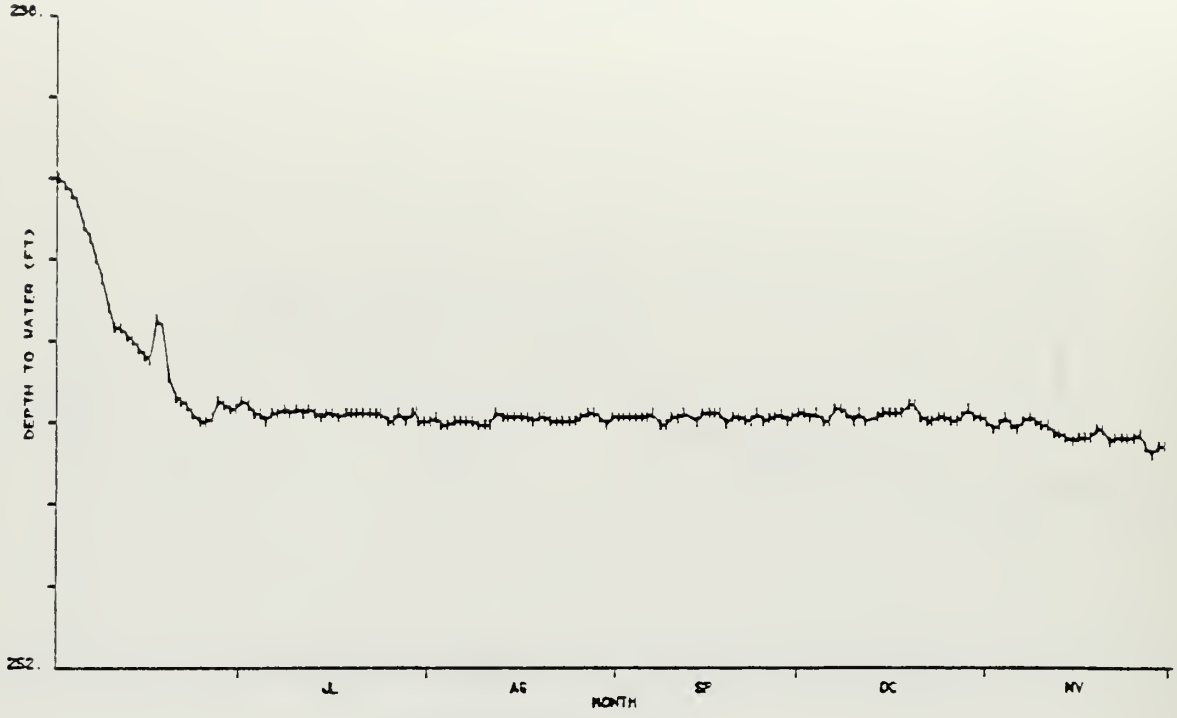


Figure 5-72

CE-707 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

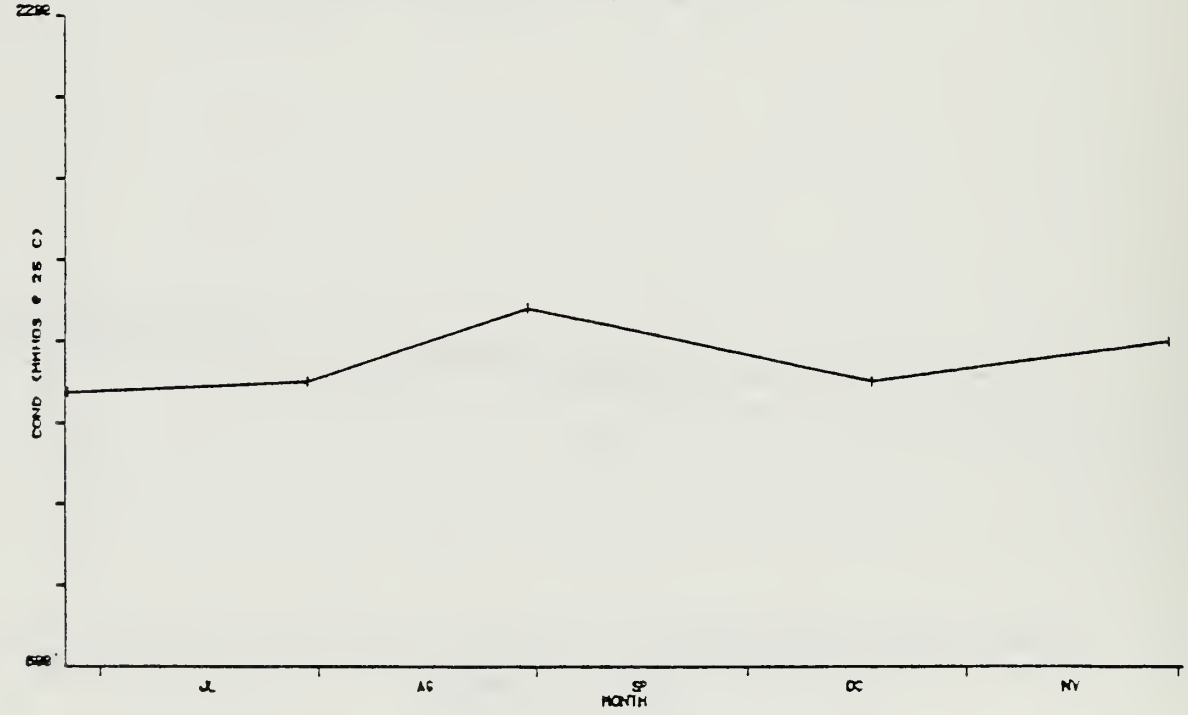


Figure 5-73

CE-707 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

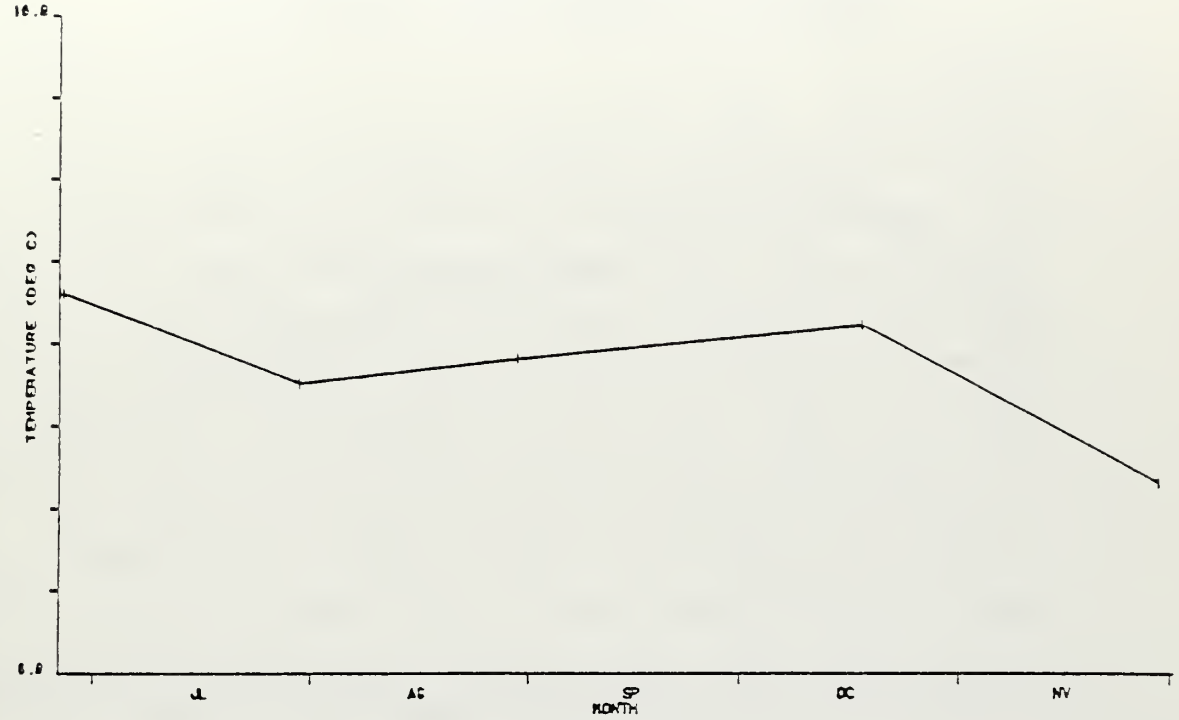


Figure 5-74

CE-707 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

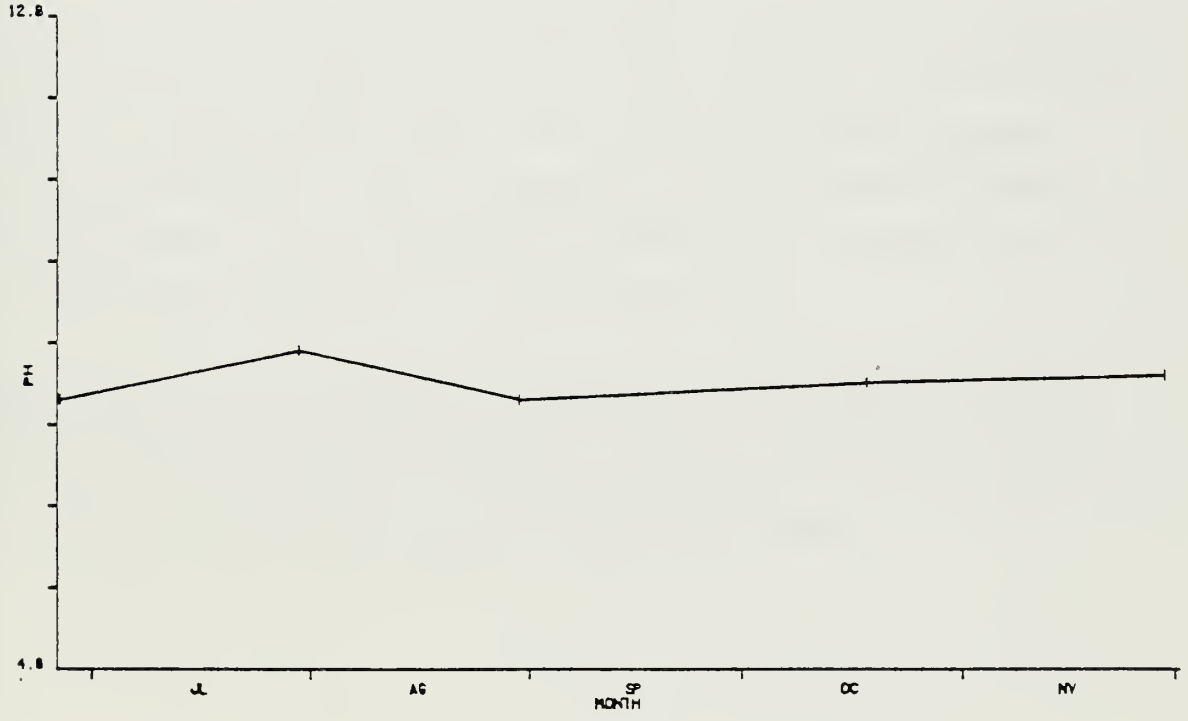


Figure 5-75

CE-708 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

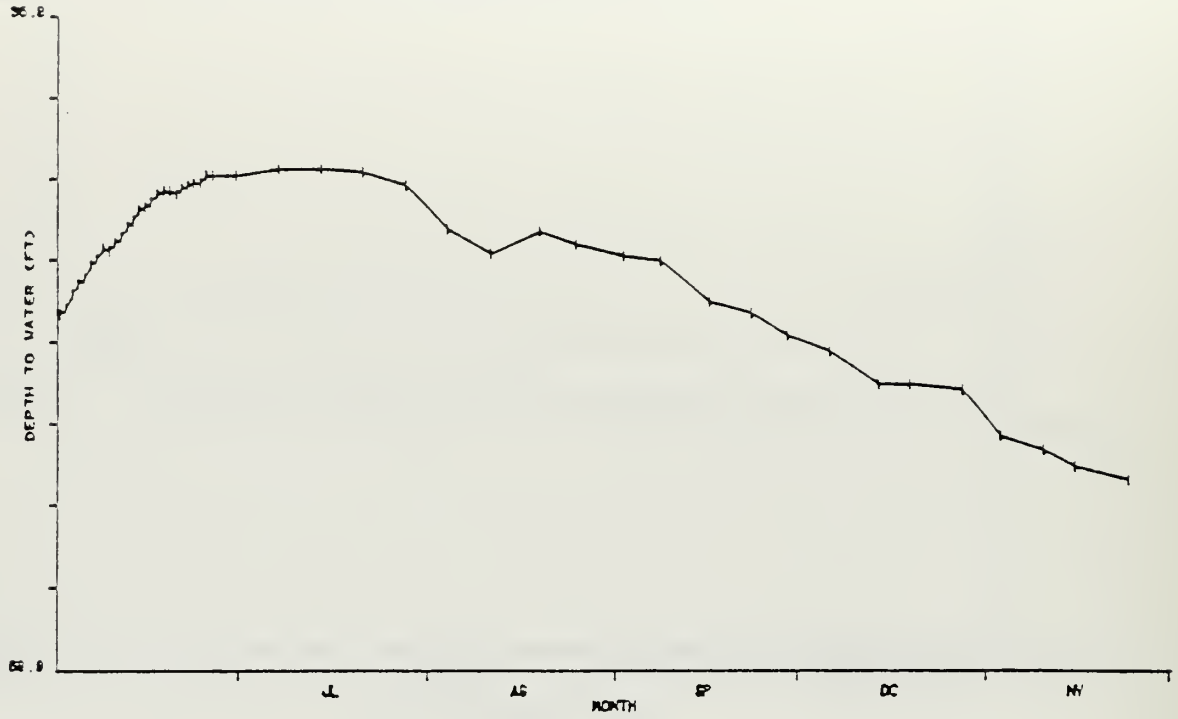


Figure 5-76

Physical data for CE-709 upper are shown on Figures 5-77 through 5-80. This monitoring hole is located in relatively close proximity to the major mining activities on-Tract, including the mine dewatering flume. The hydrograph for this hole indicates rapid and dramatic changes in water level, which are assumed to be associated with the mine and reinjection activities, as well as recharge to the upper aquifer through Corral Gulch. The water level drops rapidly in early June, remains relatively constart for approximately a month, rises rapidly in July, stabilizes again in mid-July and remains relatively constant until mid-September at which time it rapidly drops again, decays to a low point in late October then once again rises rapidly in early November. At the end of the reporting period, the water level appears to have peaked and is declining, in a manner similar to its behavior in July and August. The conductivity graph does not show an identifiable correlation of water quality with the dramatically changing water table. The conductivity appears to have increased with time with some fluctuations throughout the reporting period. The temperature plot indicates a decline from July to November, with a single reading in October that is unusually high. The pH plot is similar in shape to the temperature plot, with a high reading in October.

The hydrograph for G-S 1 is shown on Figure 5-81. This monitoring station is located near the western border of the Tract, some distance from the dewatering operation. The water level shows a rise from June through September, followed by a mild decline. This is assumed to be due to natural seasonal recharge with minimal if any influence from dewatering. An anomalously low reading during August appears to be a measurement error.

The hydrograph for G-S 2-3 is shown on Figure 5-82. The steady decline in water level indicated by these measurements show that this monitoring hole is within the cone of influence of the dewatering operation. One anomalous reading in October could be the result of measurement error.

CE-709 UPPER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

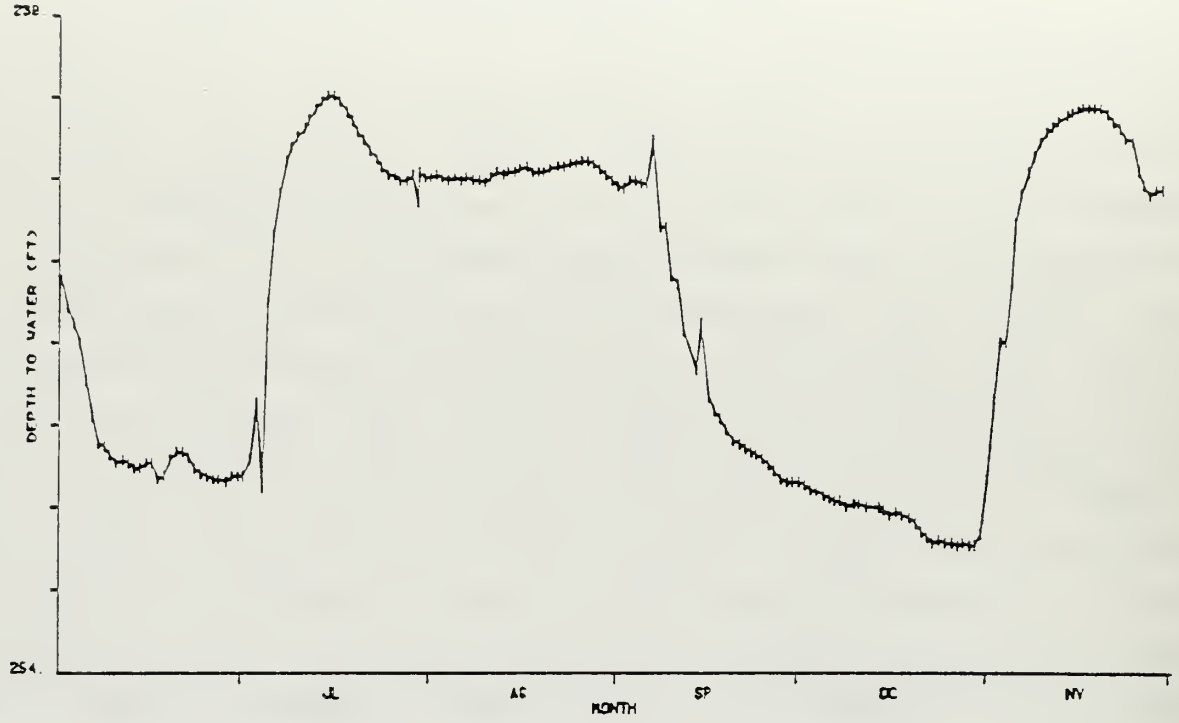


Figure 5-77

CE-709 UPPER, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

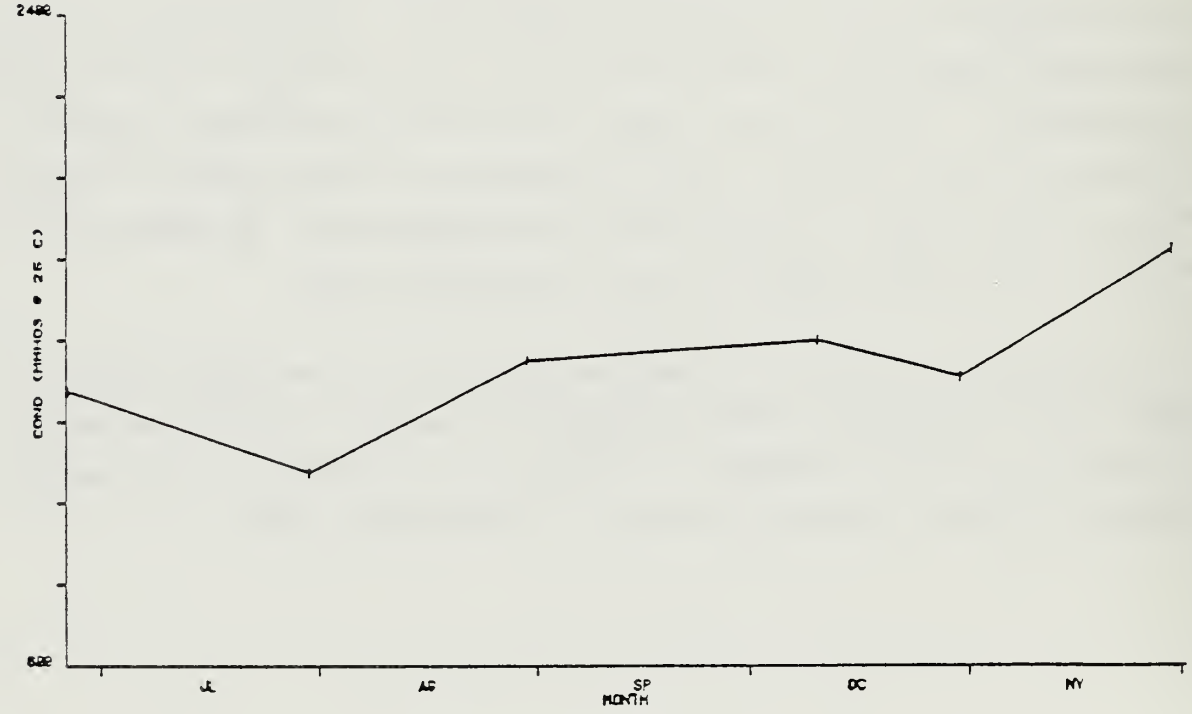


Figure 5-78

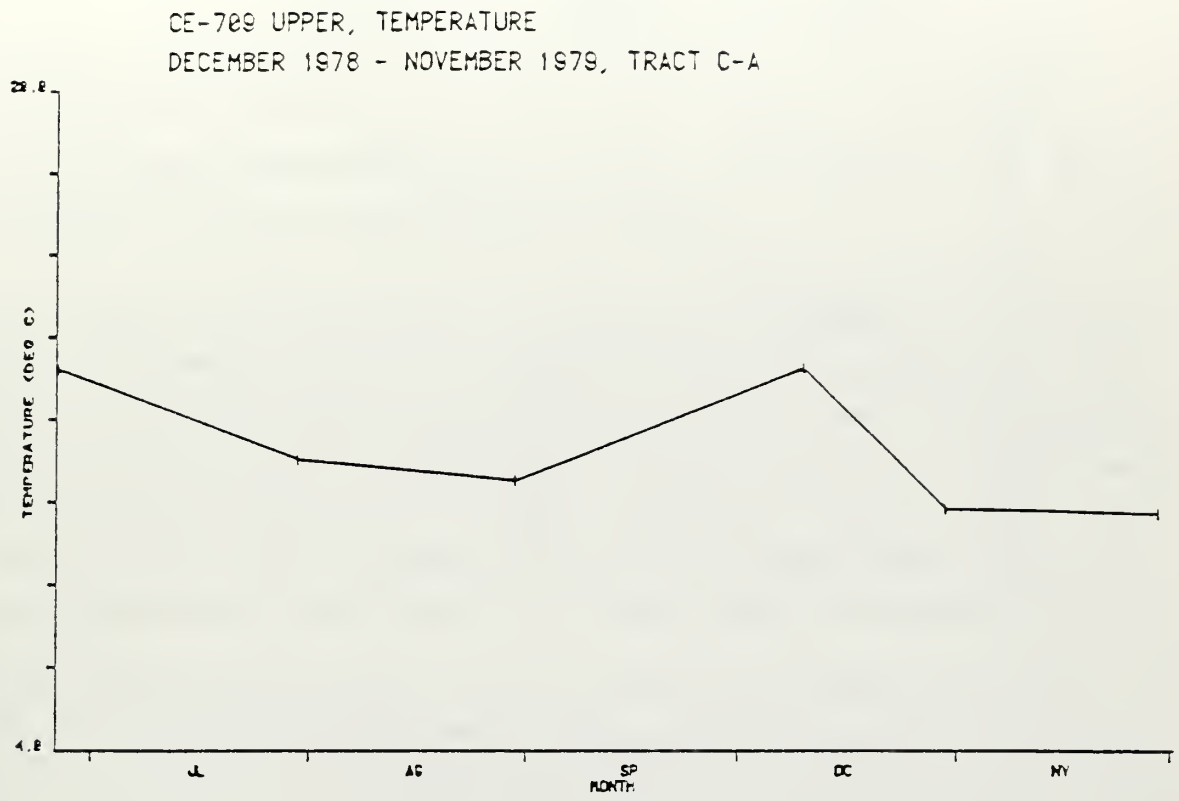


Figure 5-79

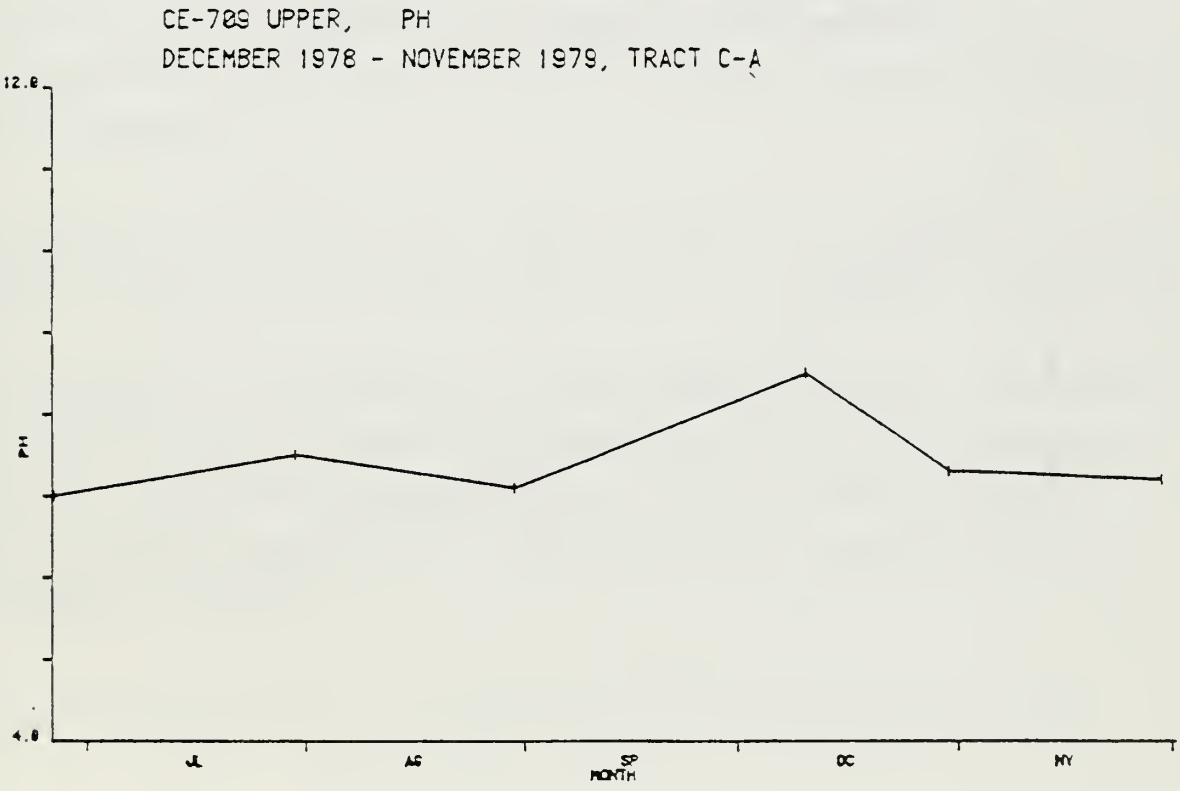


Figure 5-80

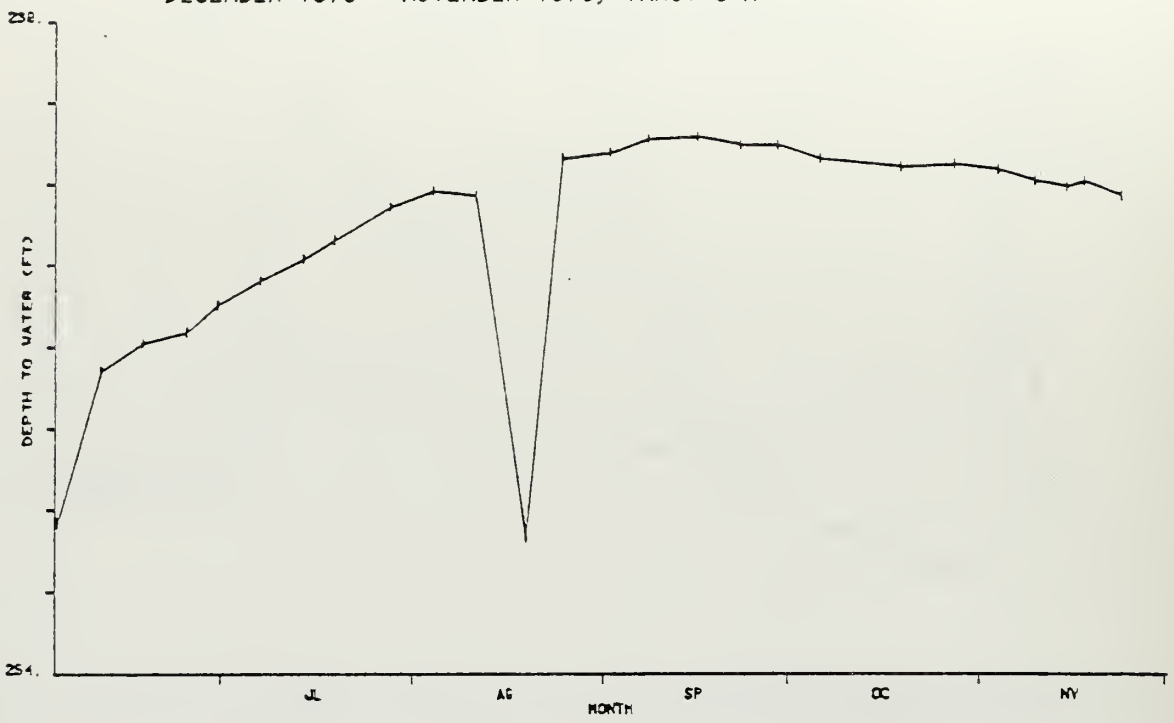


Figure 5-81

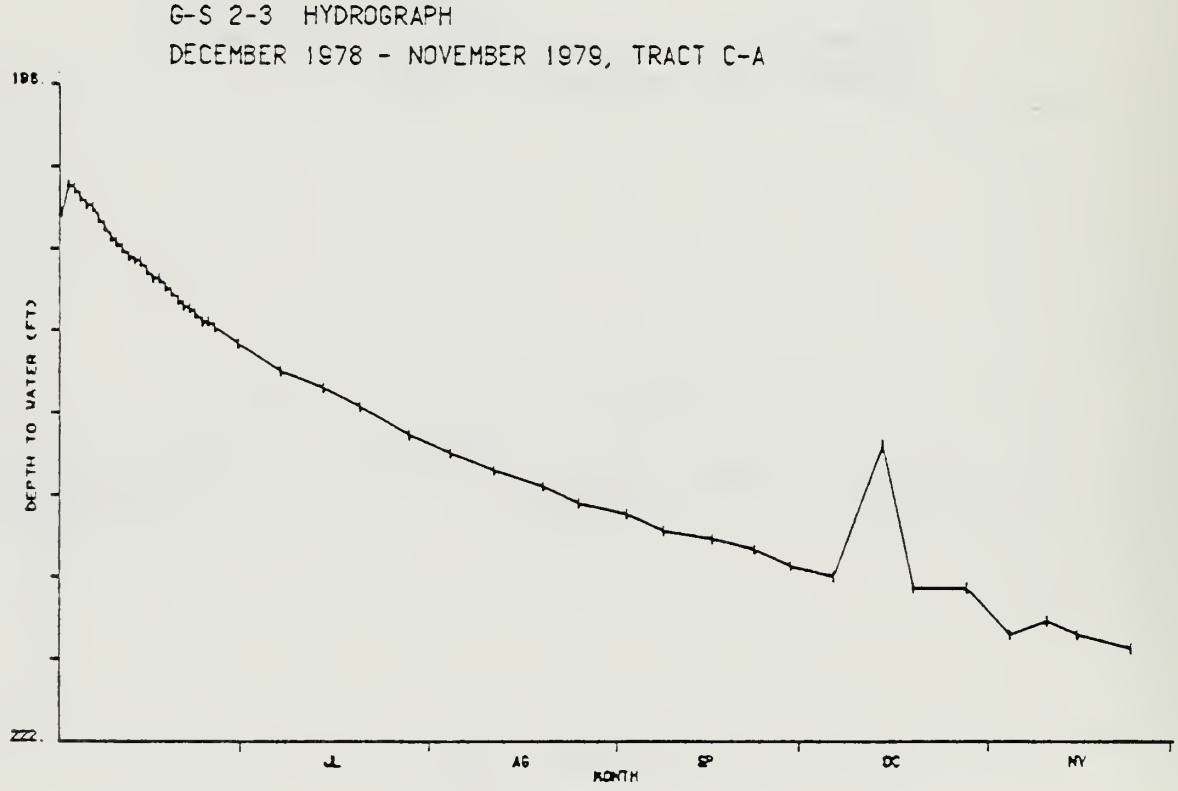


Figure 5-82

The hydrograph for G-S 4-5 upper is shown on Figure 5-83. This hydrograph also is influenced by dewatering and reinjection. However, one anomalous reading during August may be the result of water infiltrating into the deep aquifer from the alluvium in Corral Gulch.

The physical data for G-S 9 are given in Figures 5-84 through 5-87. This hole is located in the graben and does not respond to dewatering operations. The hydrograph for this hole shows a steady increase through June, July and August followed by a steady decline from September through November from the influence of natural recharge. There are only minor fluctuations in water level in this hole. Conductivity is fairly constant with one low reading during late July. Temperature fluctuations and pH remain relatively constant throughout the reporting period.

Physical data for G-S 10 are plotted in Figures 5-88 through 5-91. This hydrograph shows a steady decline in water level from June through September followed by a slight rise through the remainder of the reporting period. G-S 10 responded only to dewatering during the early portion of the project; however since reinjection was reinitiated in September, G-S 10 water levels have risen. In particular, they have risen rapidly since the reinjection capacity increased in November.

Hydrographs for G-S 12 and G-S 13 are shown on Figures 5-92 and 5-93 respectively. Water levels in both holes are steadily declining as a result of mine dewatering.

Physical data for G-S 15 are plotted in Figures 5-94 through 5-97. The hydrograph for this hole shows a steady decline from the affect of mine dewatering. Fluctuations in conductivity are considered to indicate natural variations in groundwater quality in this area. Temperature and pH fluctuate but no long-term trend is apparent.

G-S 4-5 UPPER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

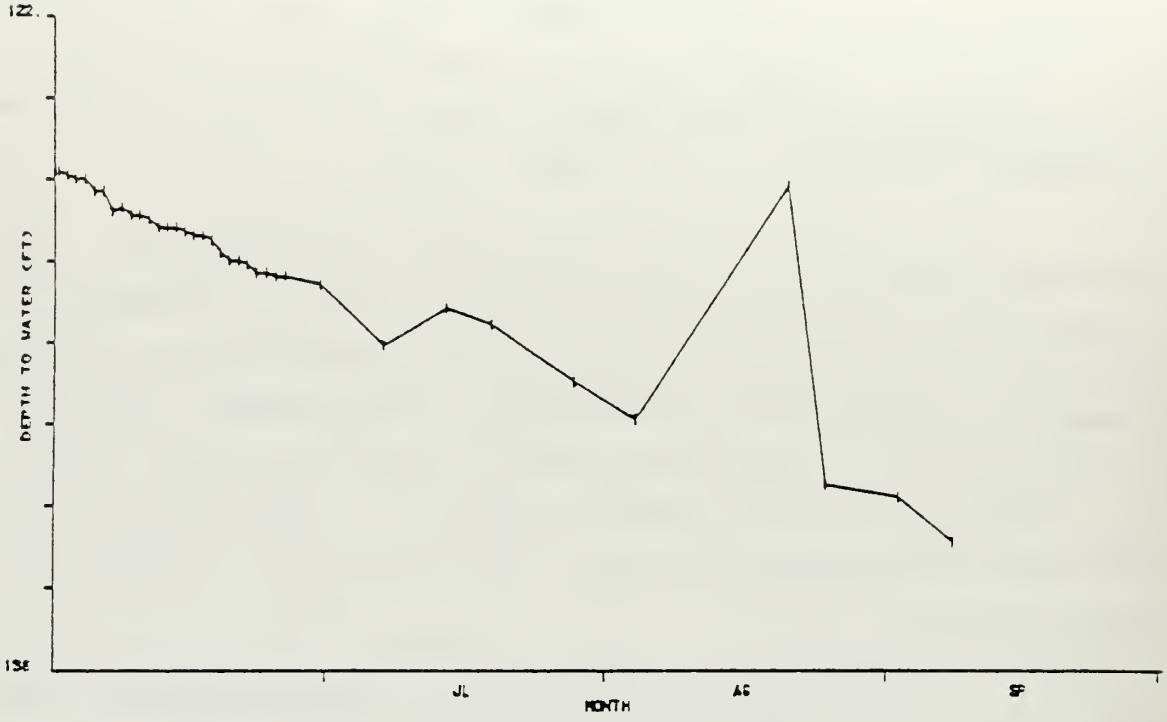


Figure 5-83

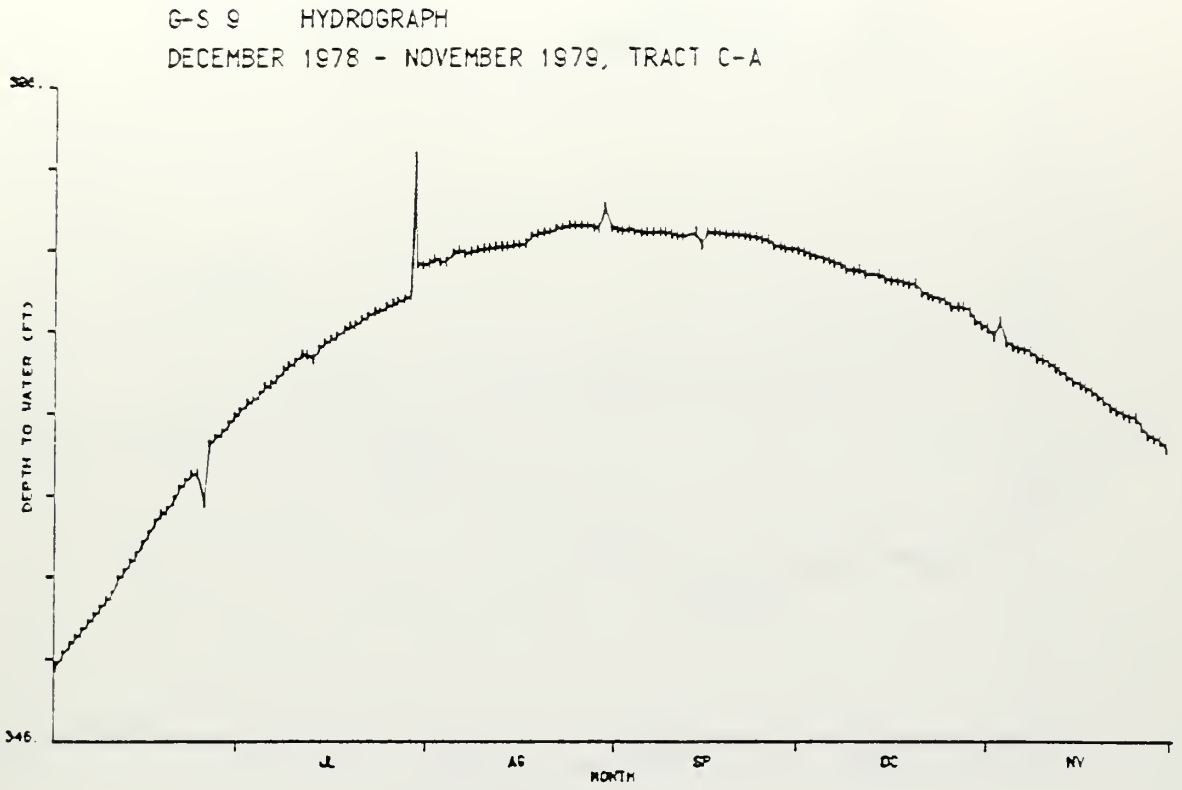


Figure 5-84

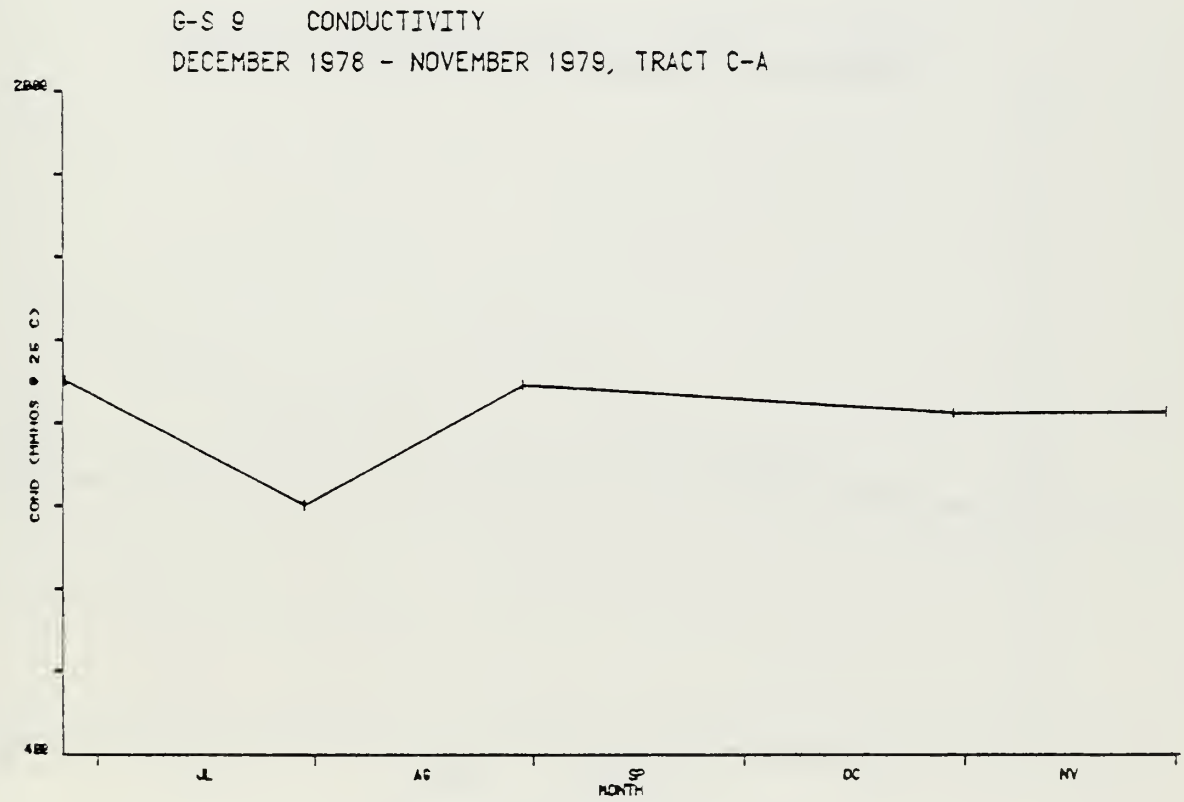


Figure 5-85

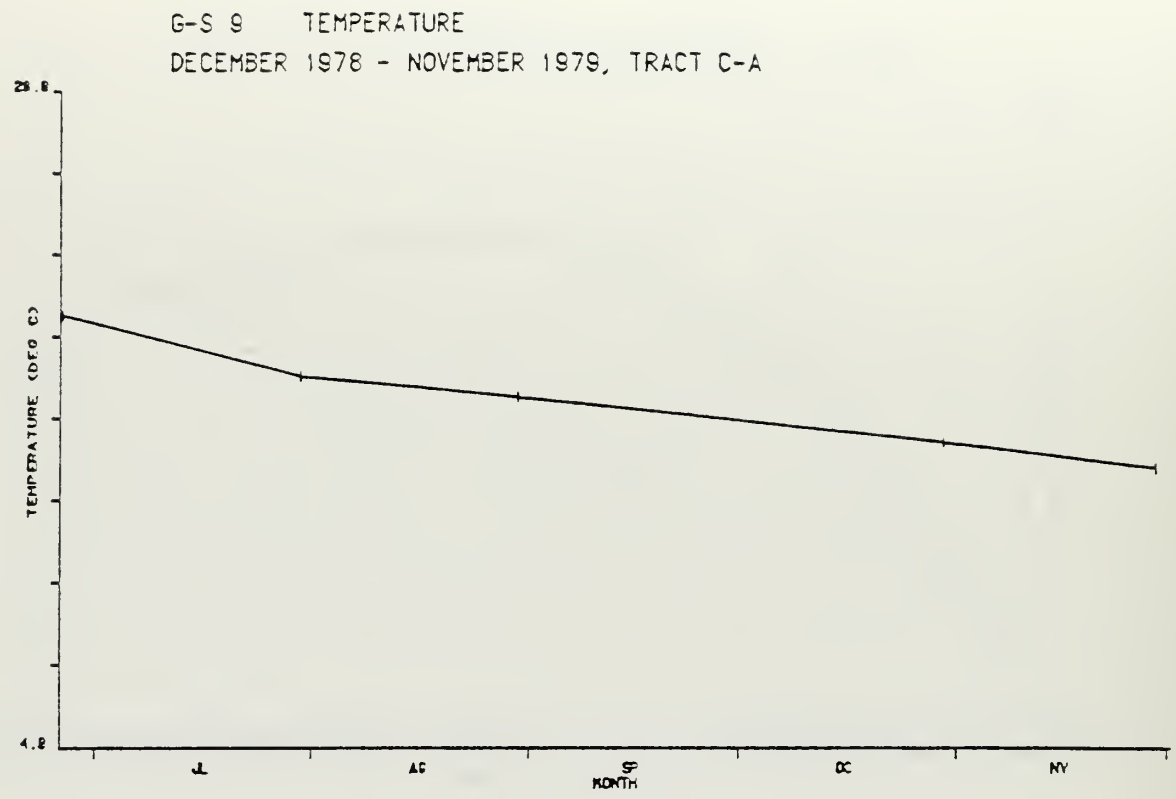


Figure 5-86

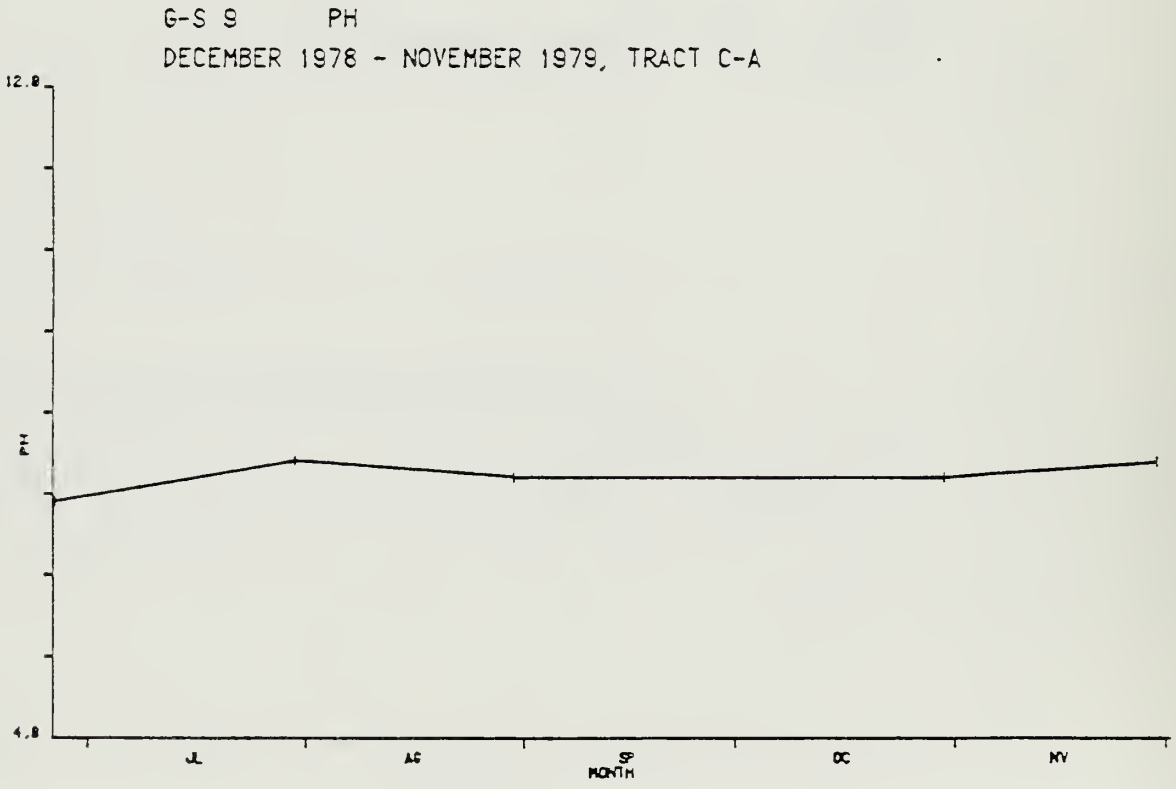


Figure 5-87

Figure 5-88

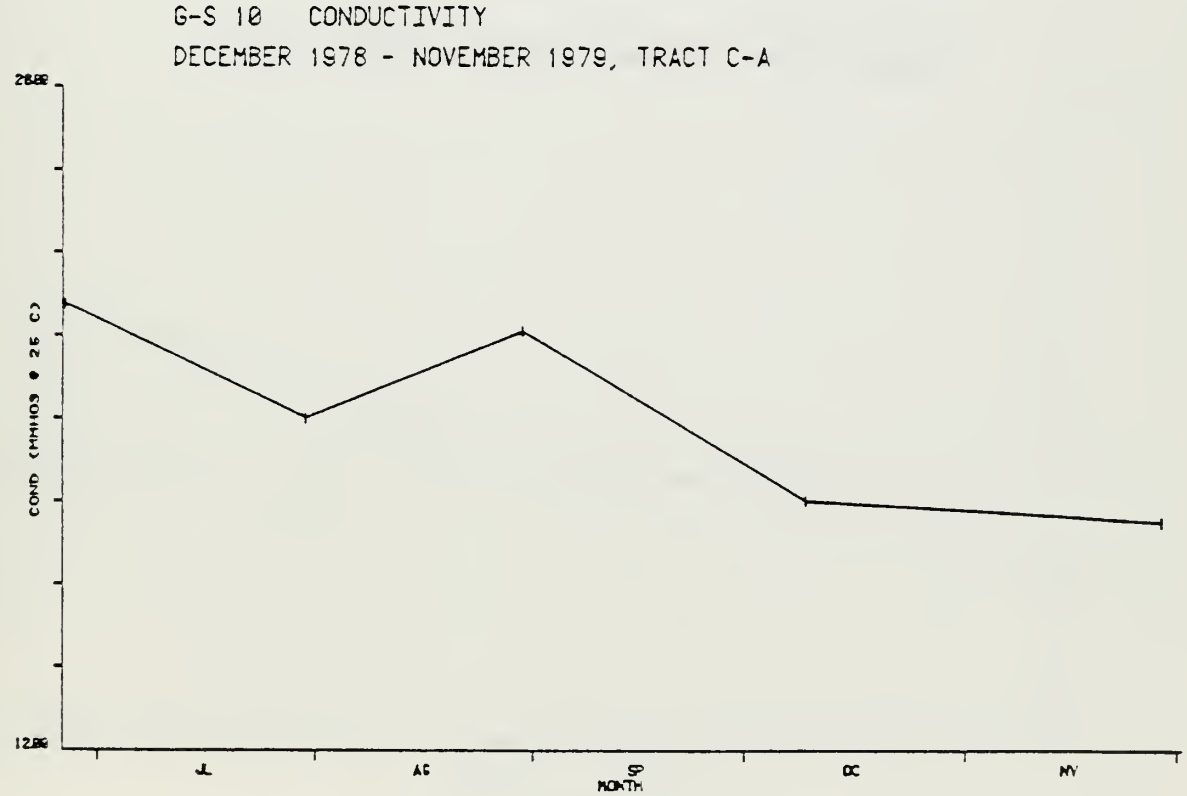


Figure 5-89

G-S 10 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

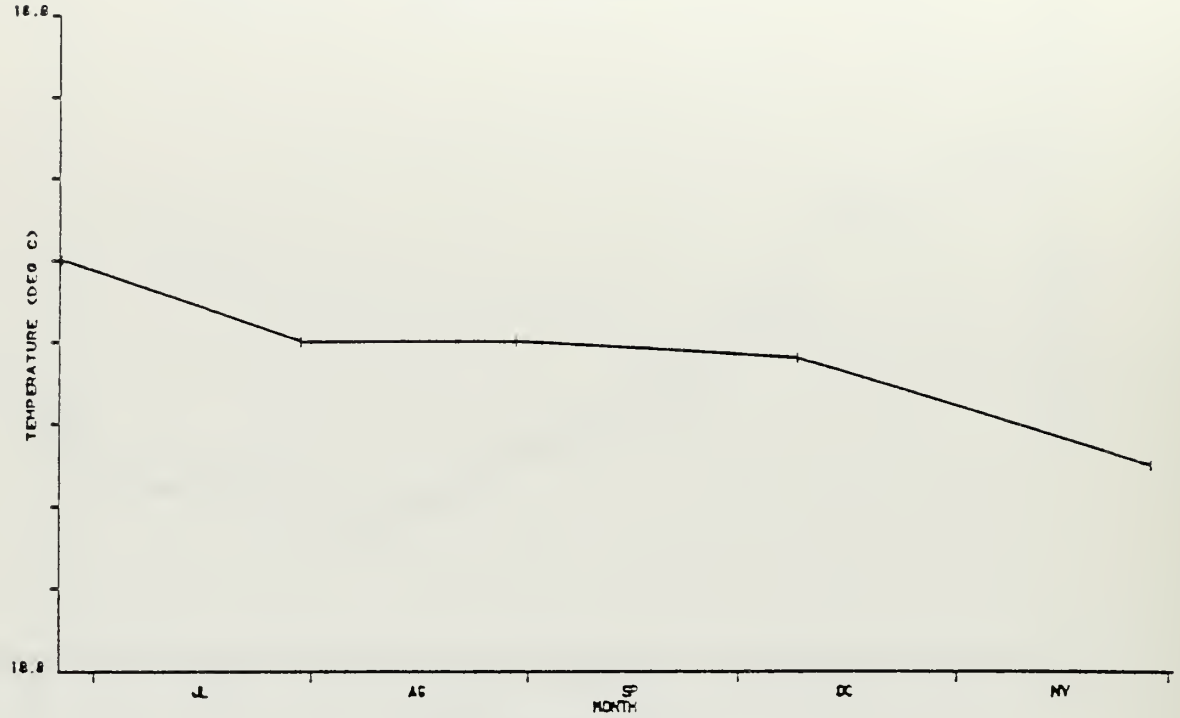


Figure 5-90

G-S 10 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

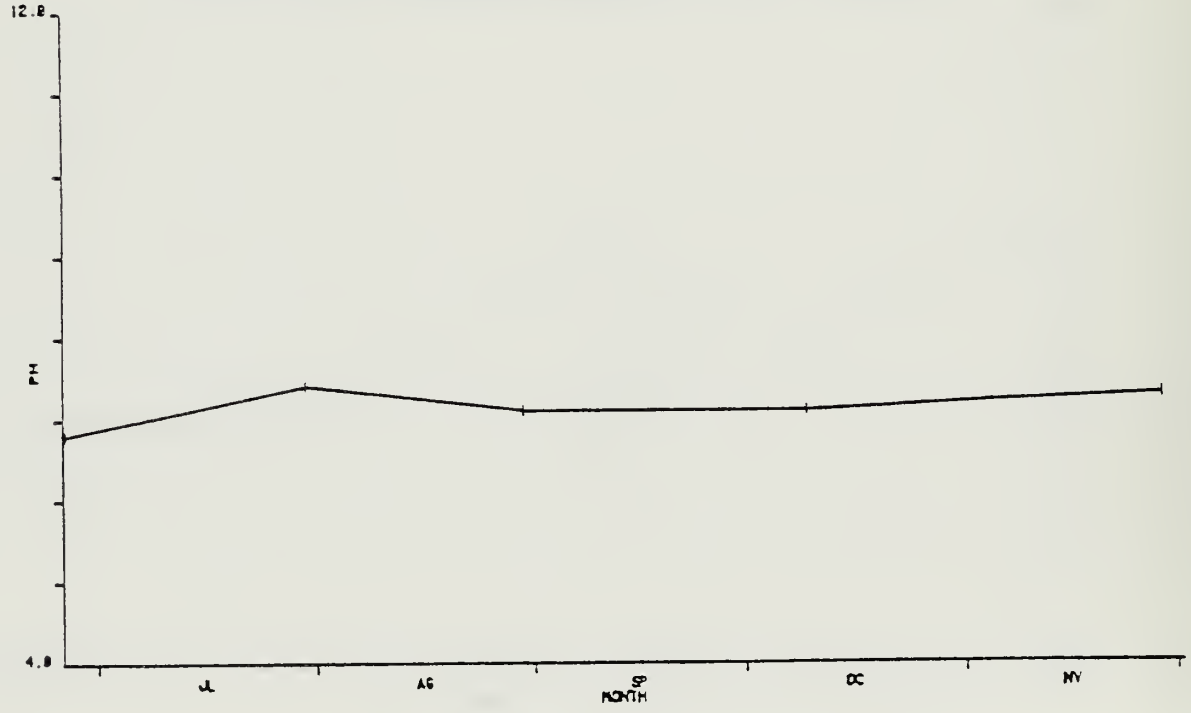


Figure 5-91

G-S 12 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

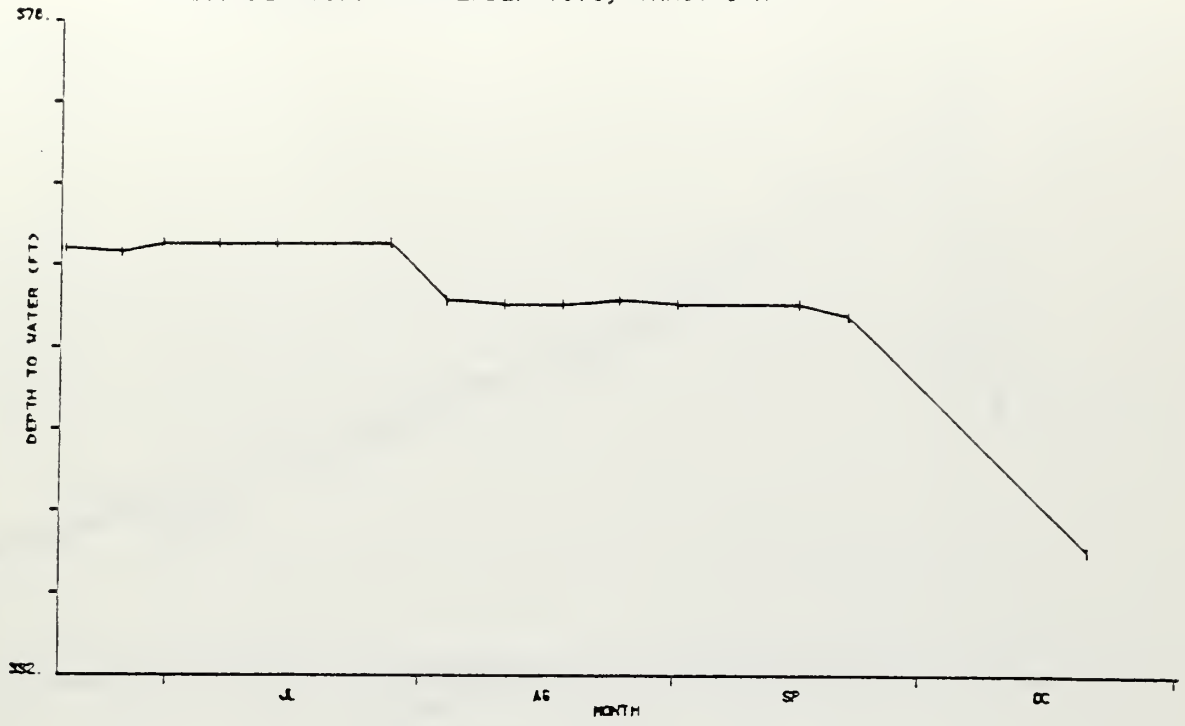


Figure 5-92

G-S 13 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

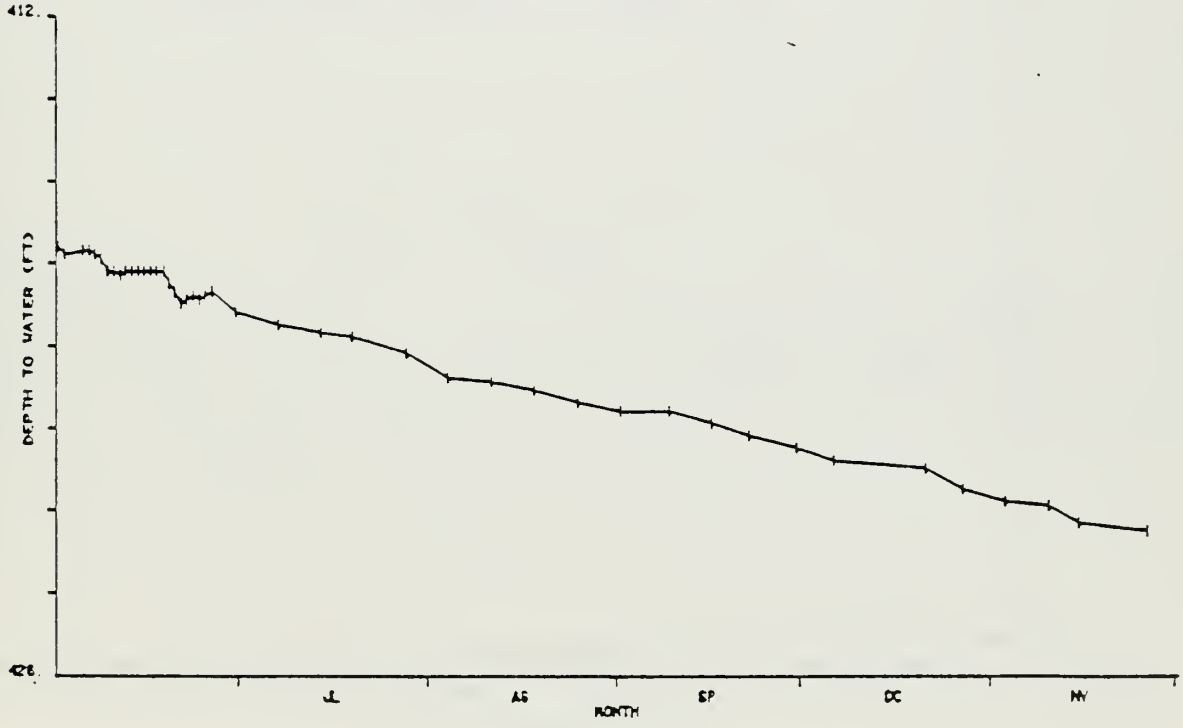


Figure 5-93

G-S 15 UPPER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

Figure 5-94

G-S 15 UPPER, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

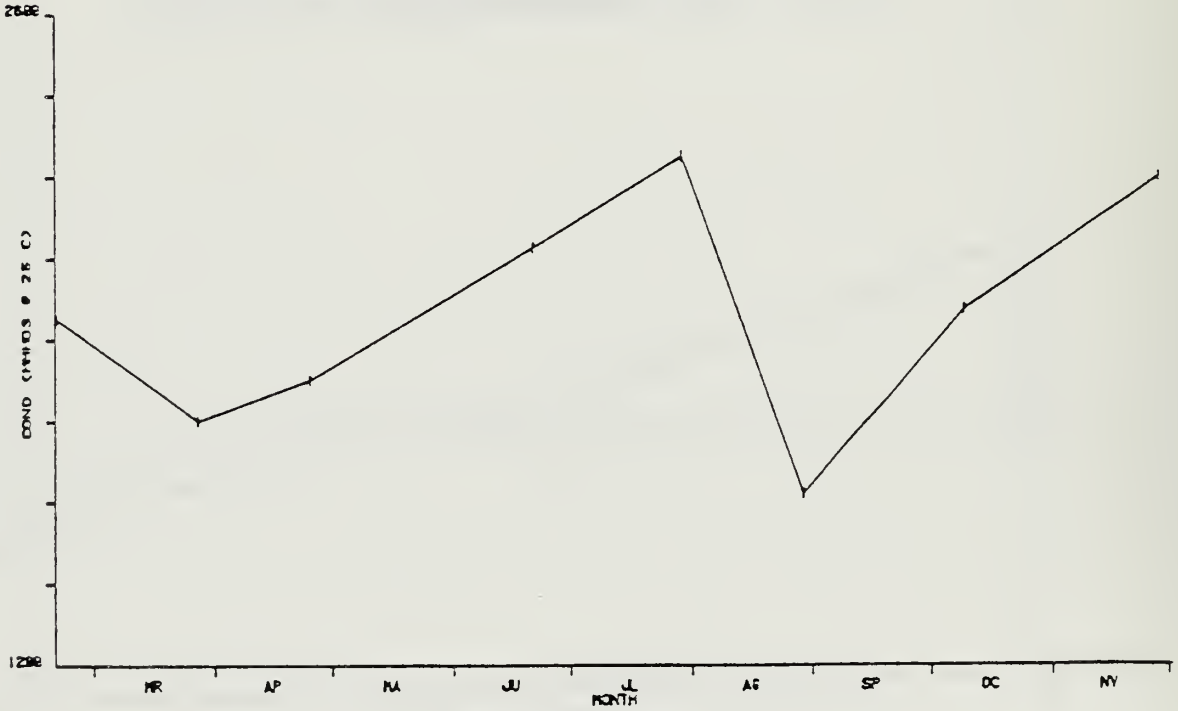


Figure 5-95

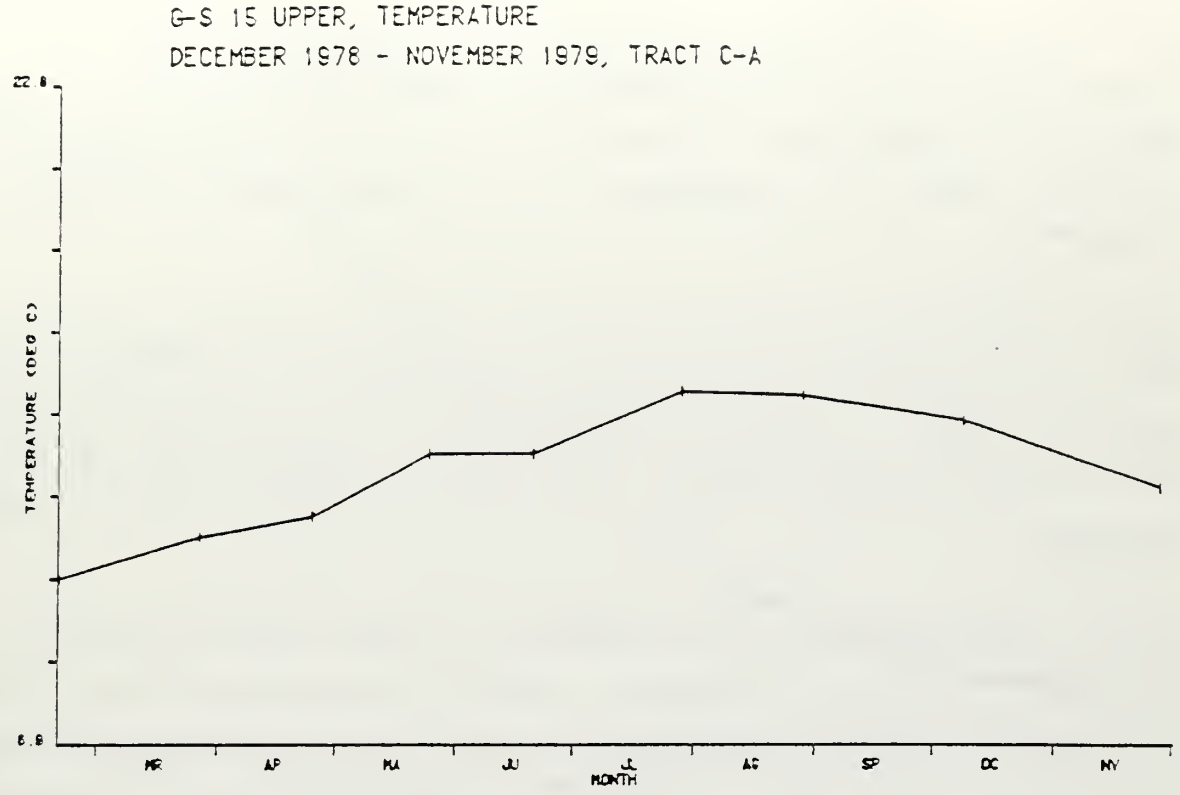


Figure 5-96

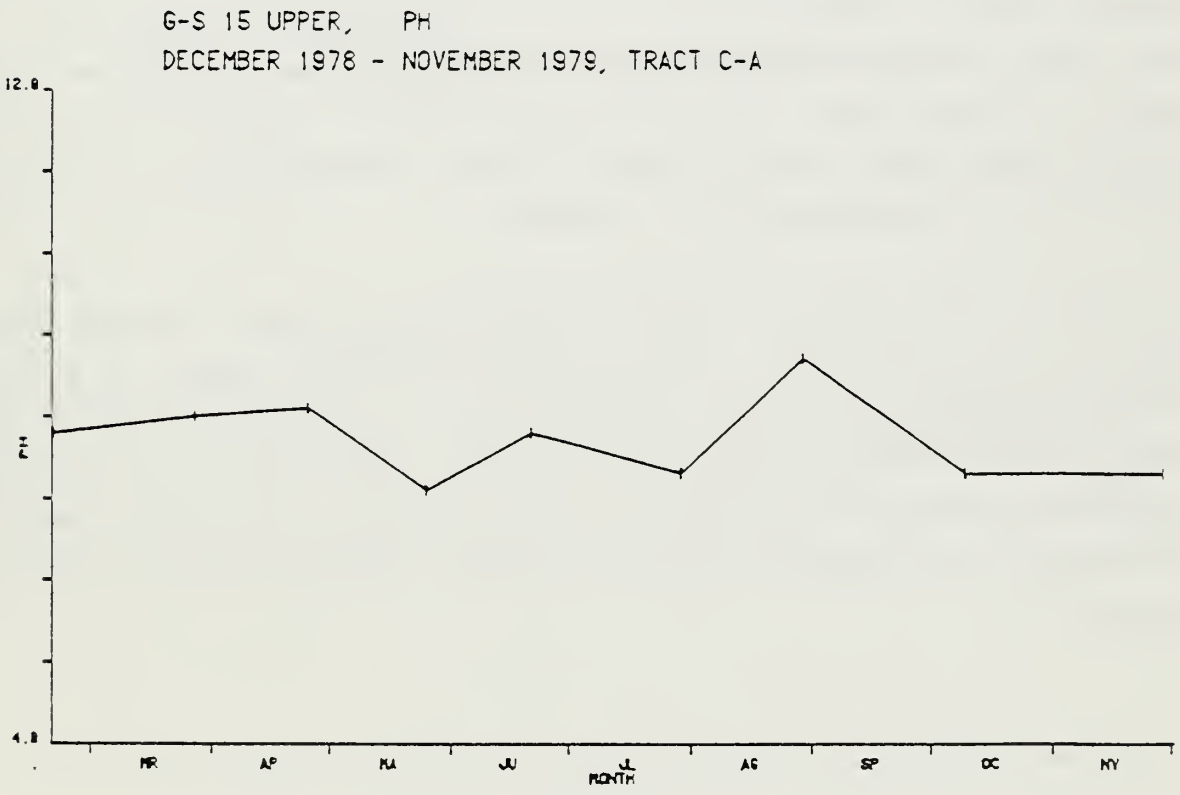


Figure 5-97

Physical data for G-S M1 are plotted in Figures 5-98 through 5-101. The hydrograph for this hole shows a steady decline, indicating the influence of dewatering. Conductivity, temperature and pH fluctuate, but no long-term trend is apparent.

Physical data plots for G-S M2 are shown on Figures 5-102 through 5-105. This well is far enough from mining activities and recharge area that the water levels are steady. Conductivity fluctuations are apparently due to the natural variation of water quality in the aquifer. Temperature and pH relatively fluctuate.

Physical data plots for G-S M3 are shown in Figures 5-106 through 5-109. The hydrograph for this hole indicates a relatively constant water level, except for a spike in late July. This rise in water level may have been due to infiltration of surface water. Conductivity, temperature, and pH fluctuate.

The plots of physical data for G-S M4 are shown on Figures 5-110 through 5-113. The water levels in this hole are relatively stable until mid-February, at which time a definite decline in water level losses sealed with the interruption of reinjection. This decline continued until August, at which time the water level stabilized at a low level when reinjection was reinitiated. Conductivity, temperature and pH fluctuate.

In general, water levels in the upper aquifer near the mine responded to dewatering and reinjection. Natural recharge affected those along the north and west portions of the Tract. Conductivity fluctuated but no major trend could be established for the Tract as a whole. Many temperature values showed a seasonal trend which is probably a local response to the casing temperature fluctuations. pH remained relatively constant although some holes showed fluctuations.

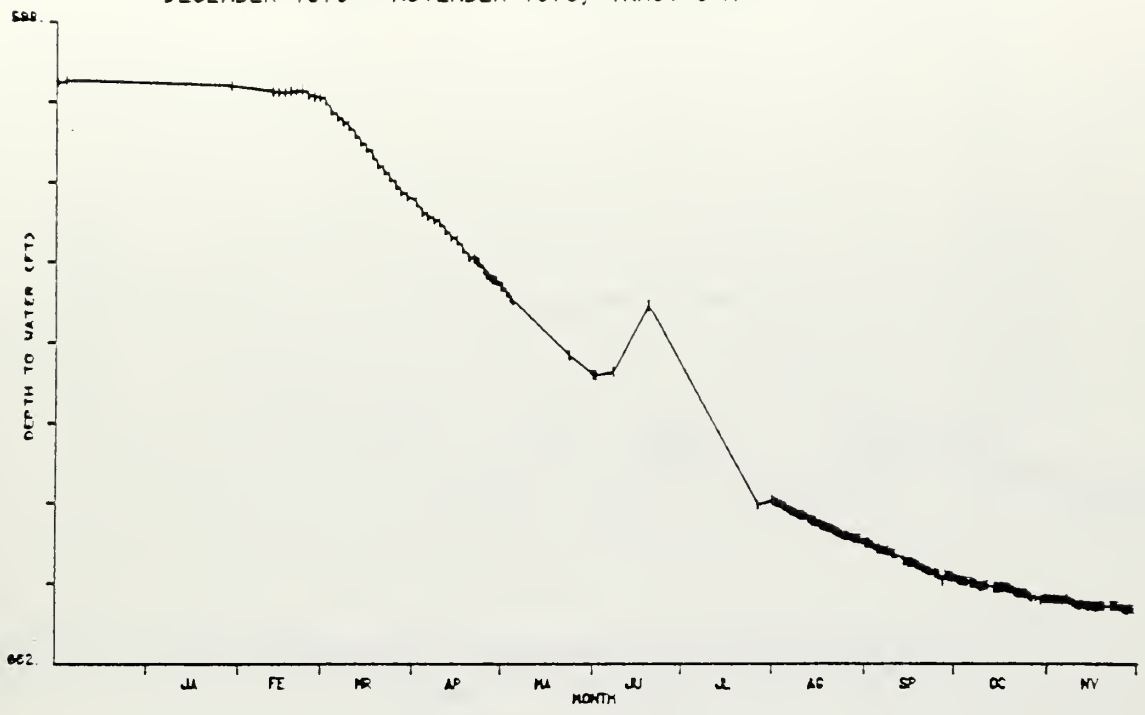


Figure 5-98

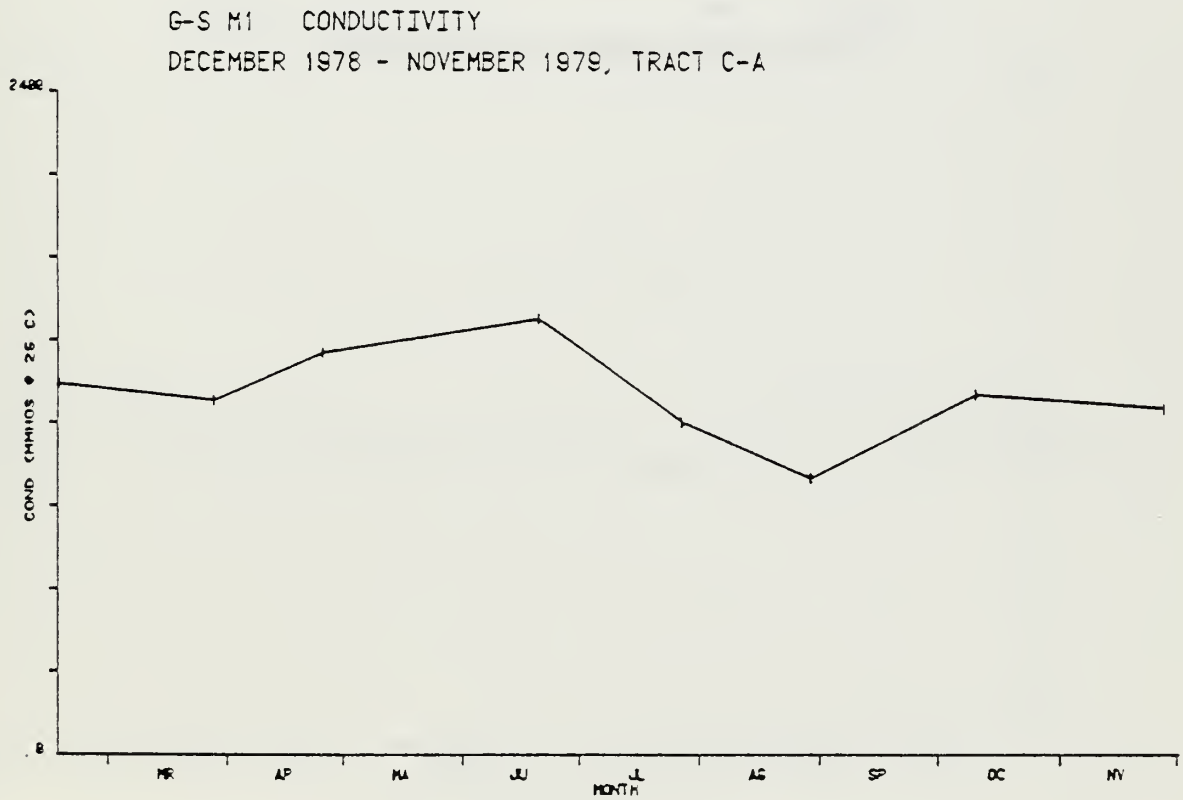


Figure 5-99

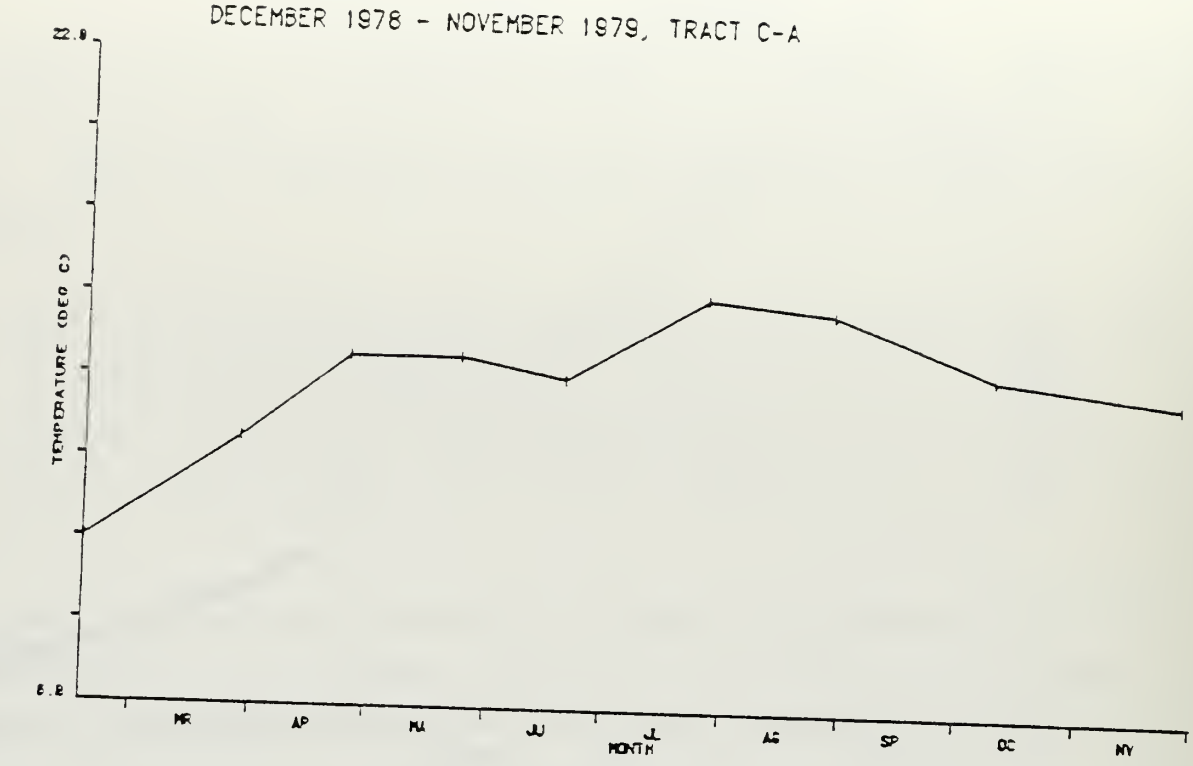


Figure 5-100

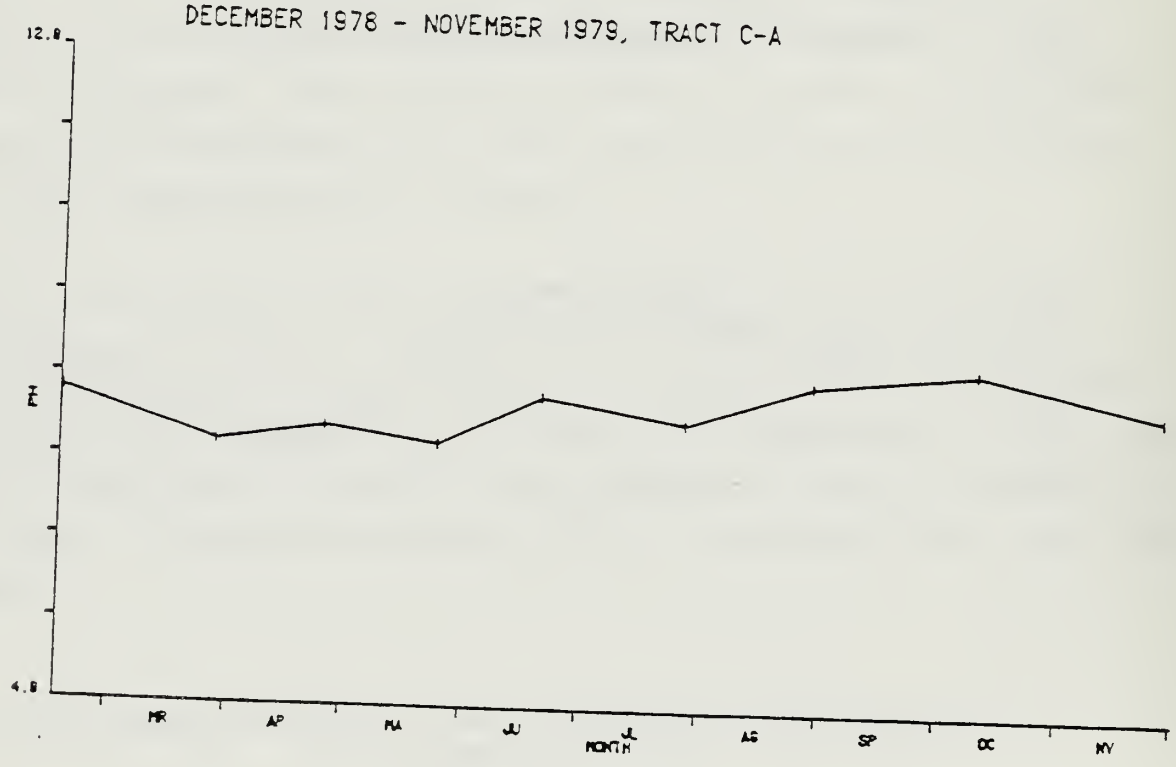


Figure 5-101

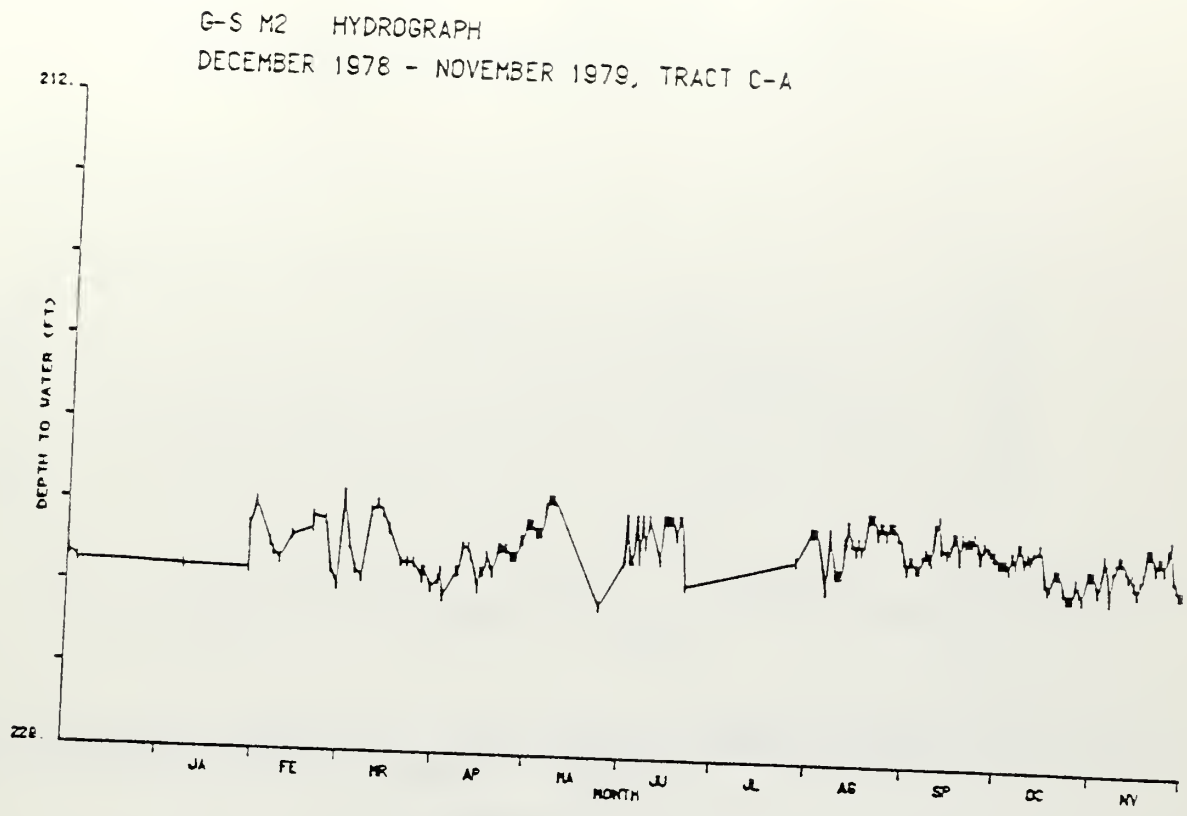


Figure 5-102

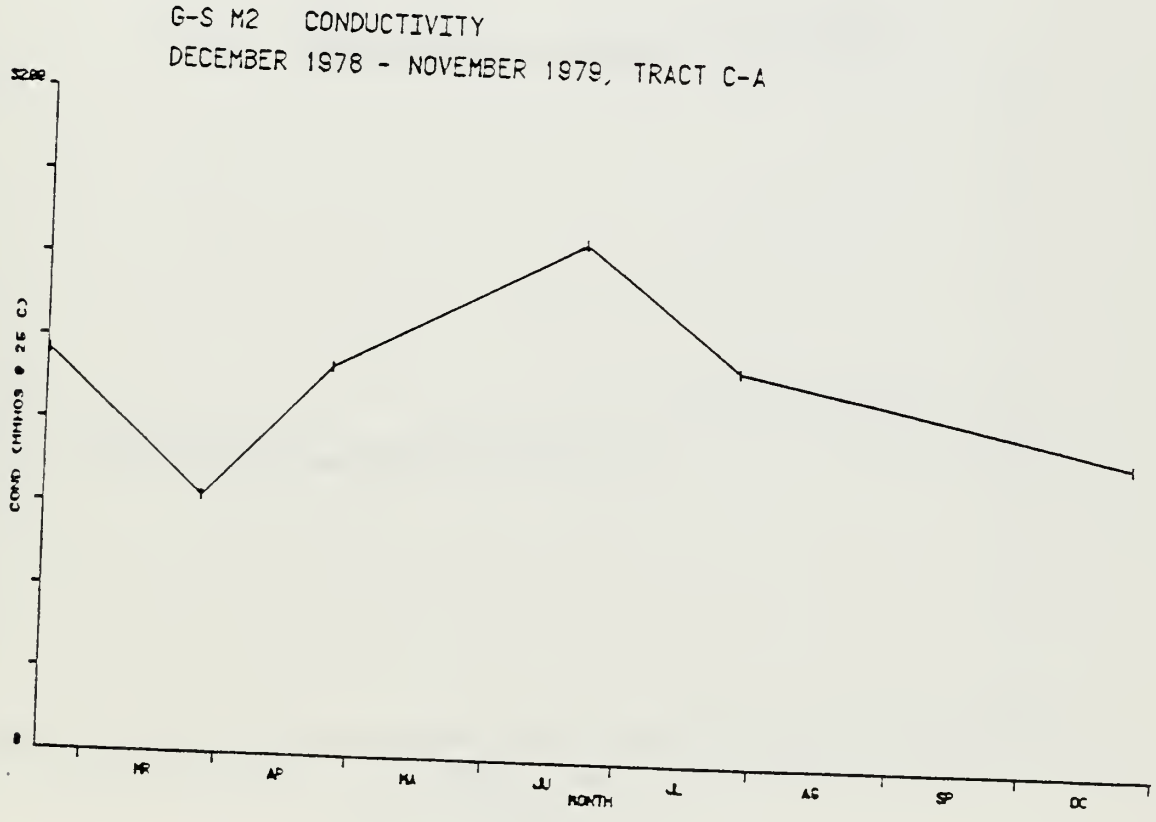
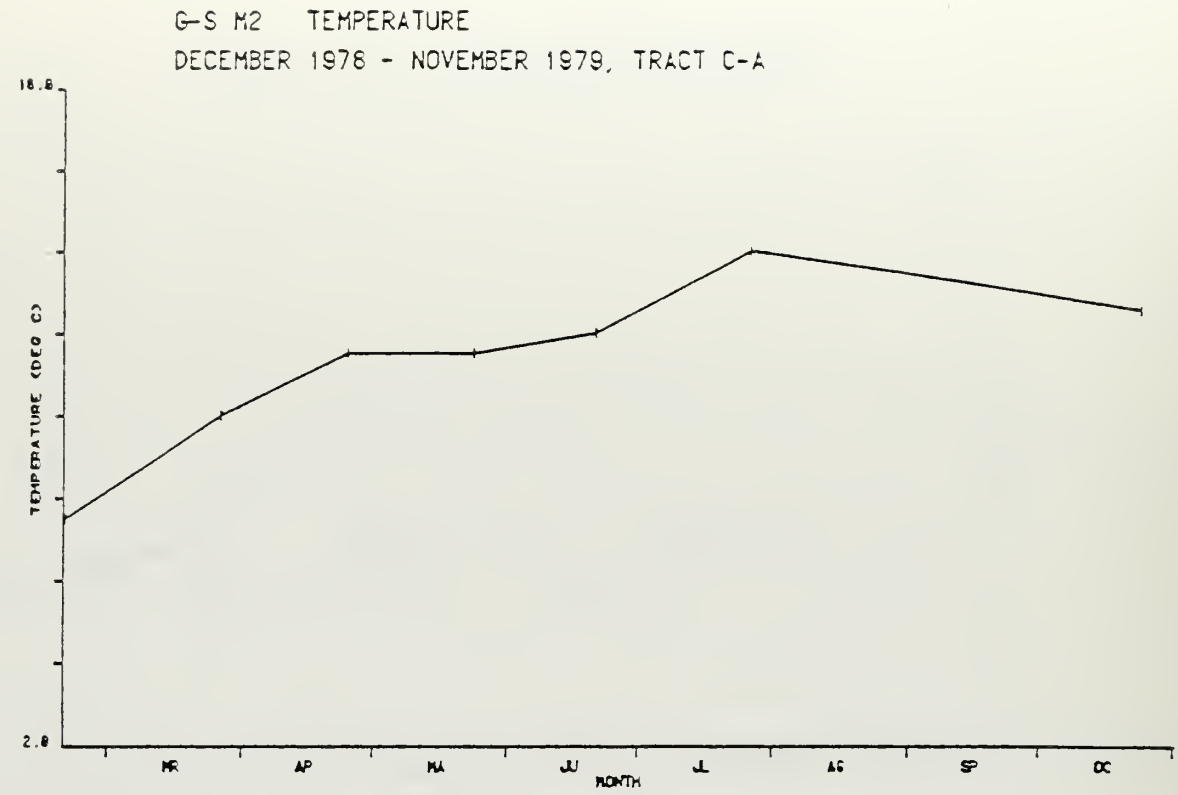


Figure 5-103



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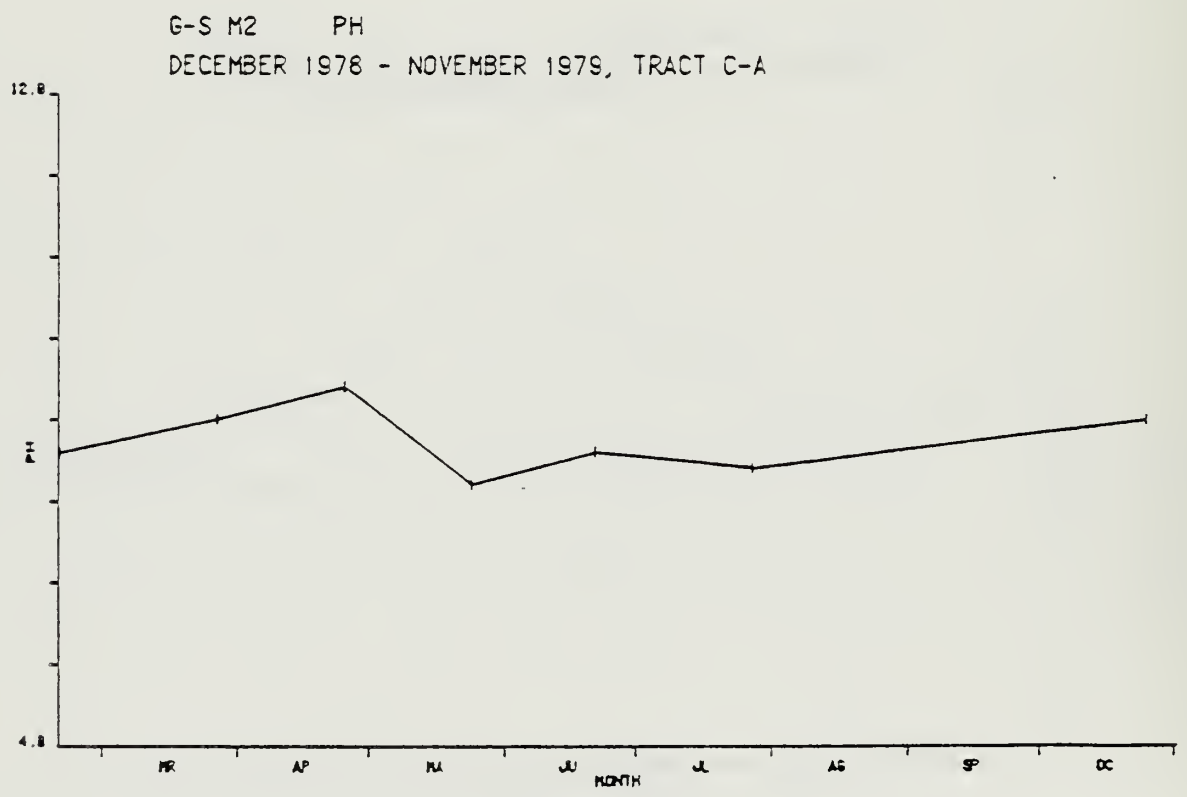

Figure 5-105

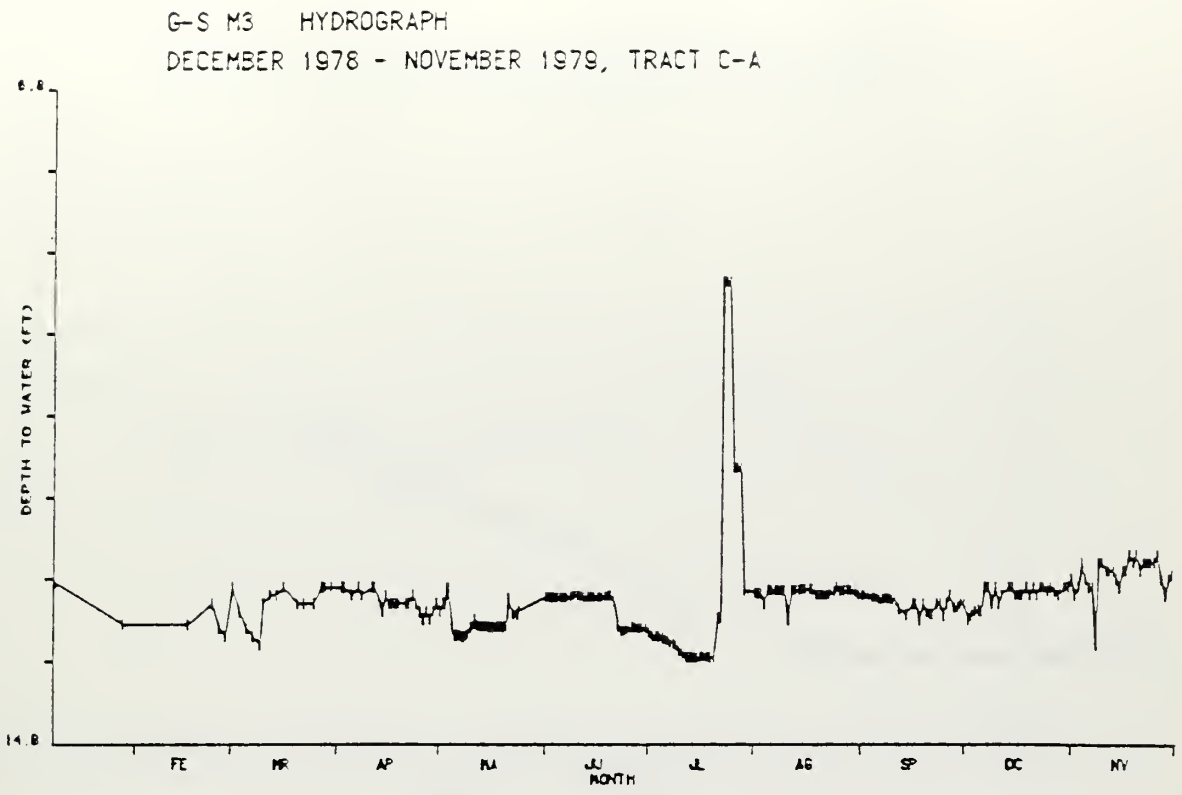

Figure 5-106

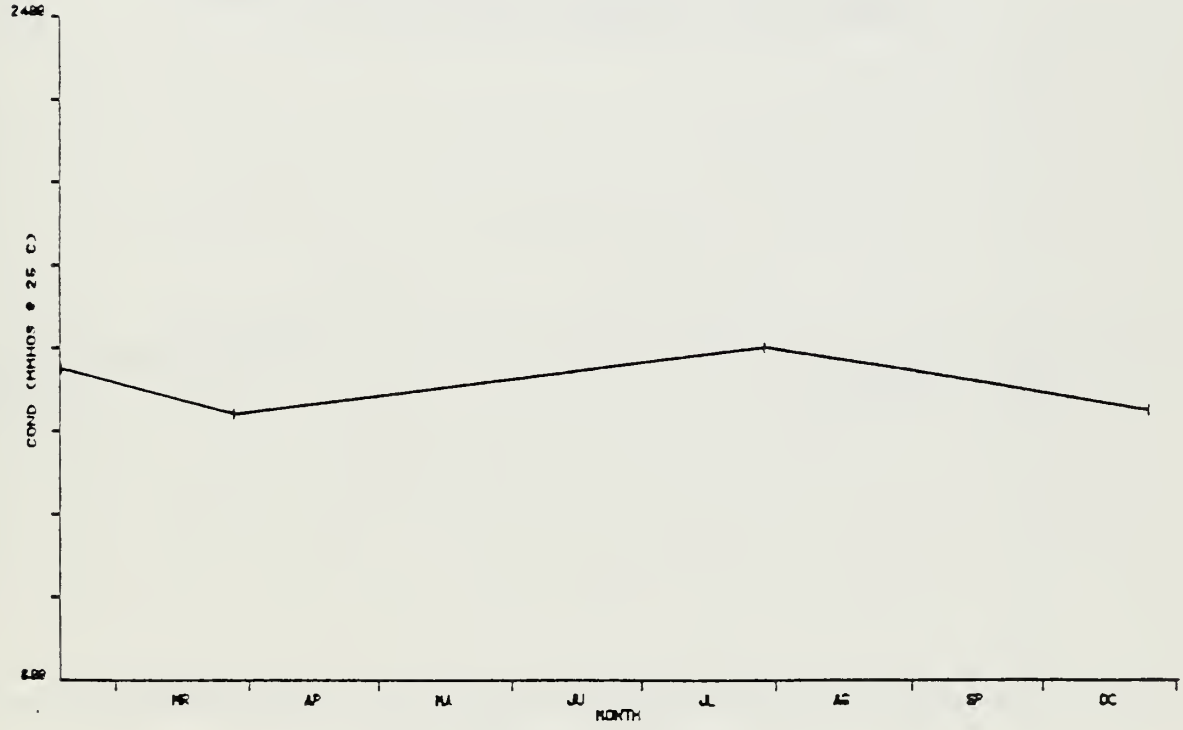

Figure 5-107

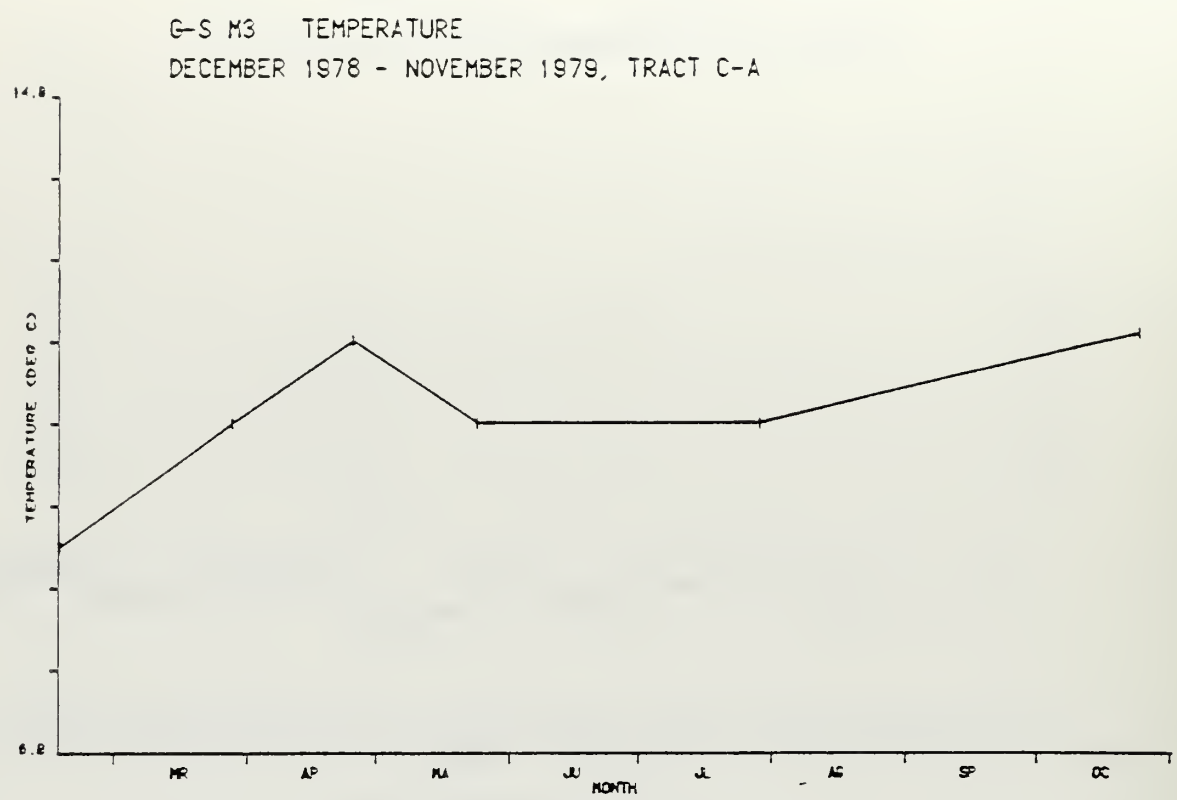

Figure 5-108

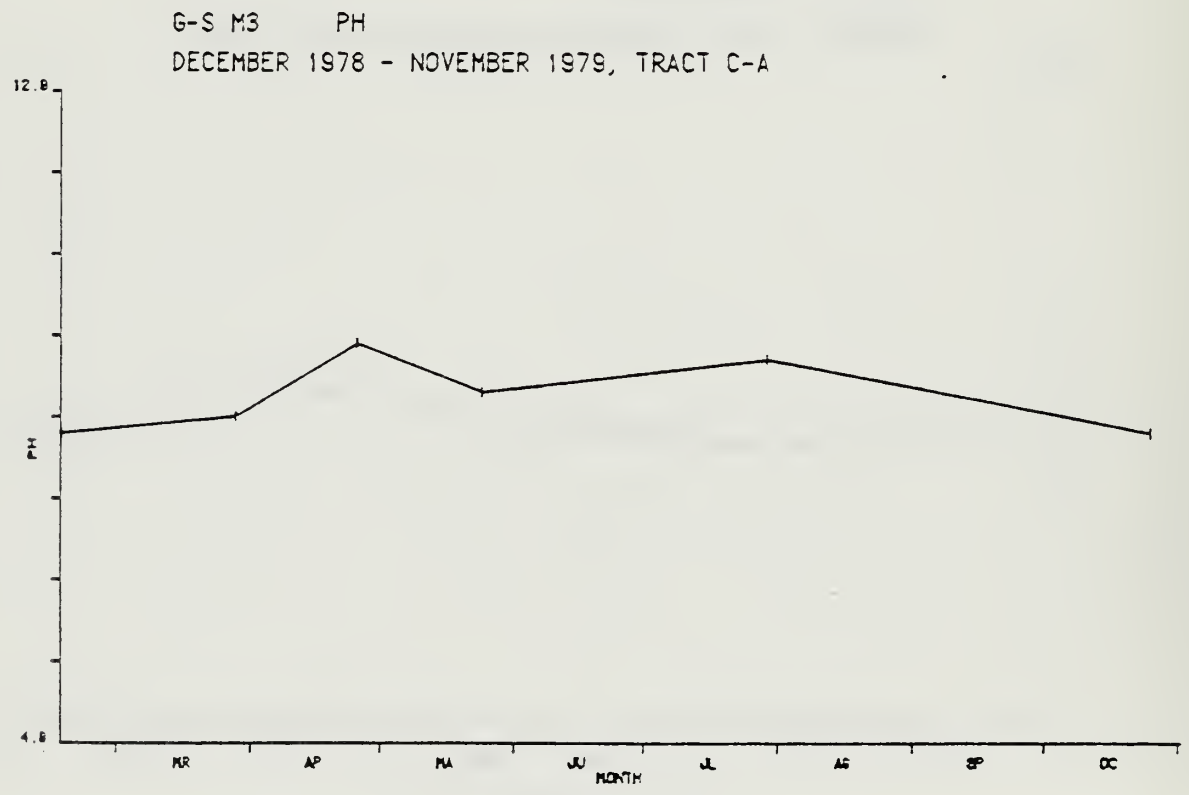

Figure 5-109

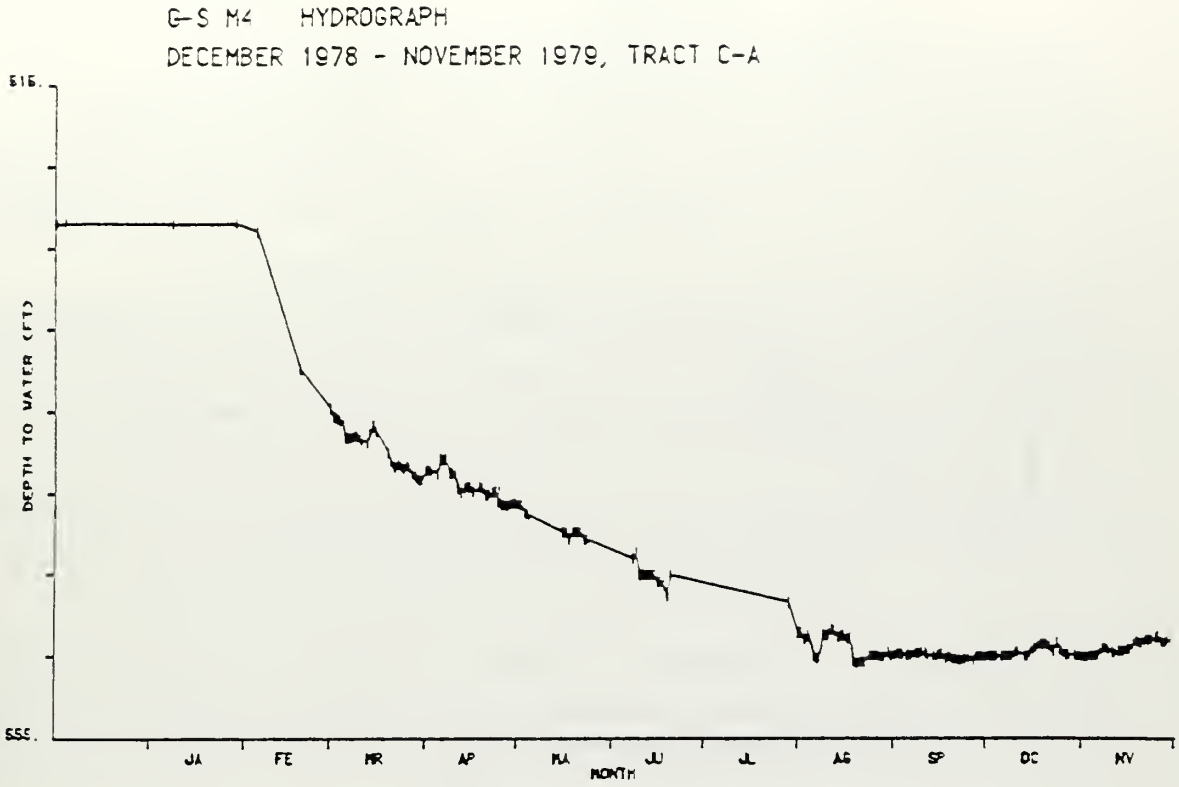

Figure 5-110

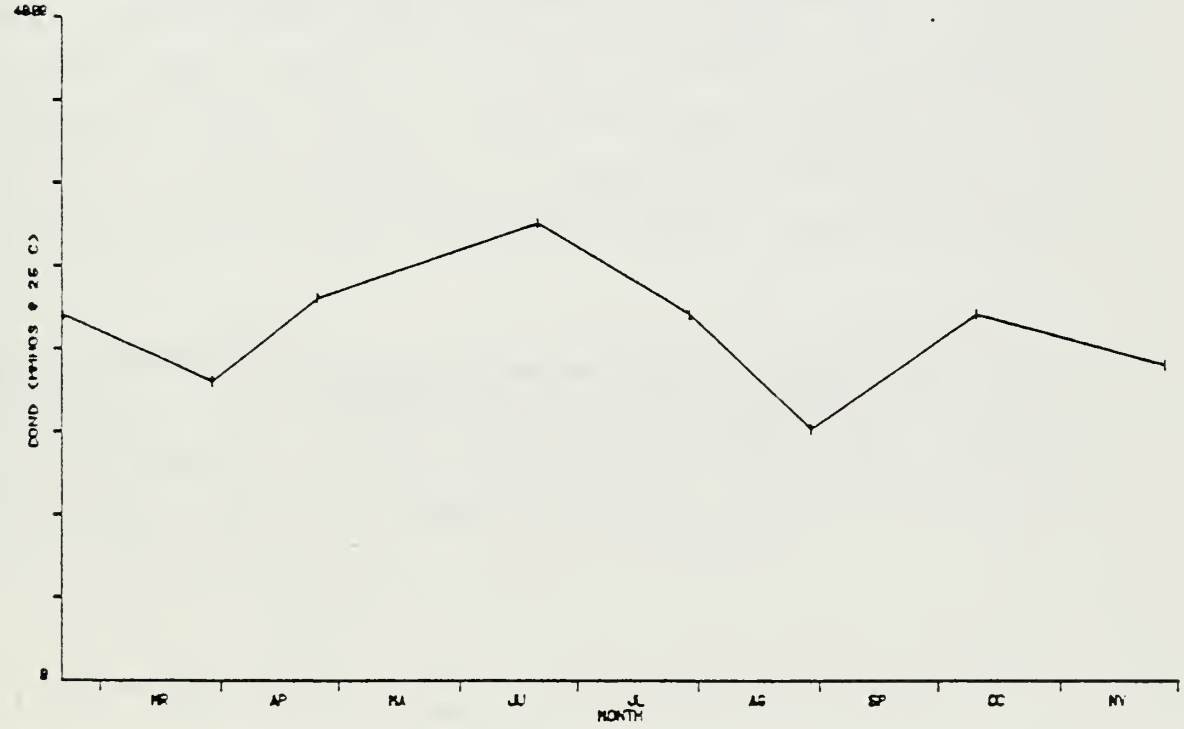

Figure 5-111

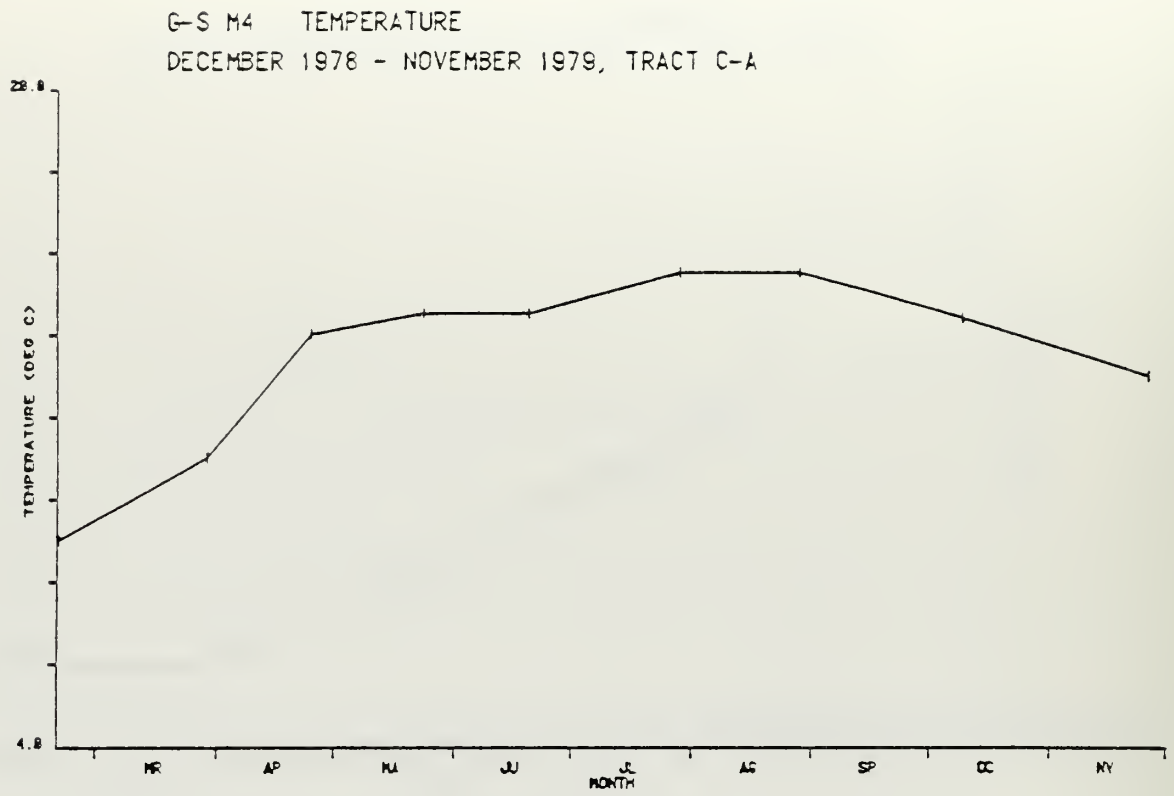

Figure 5-112

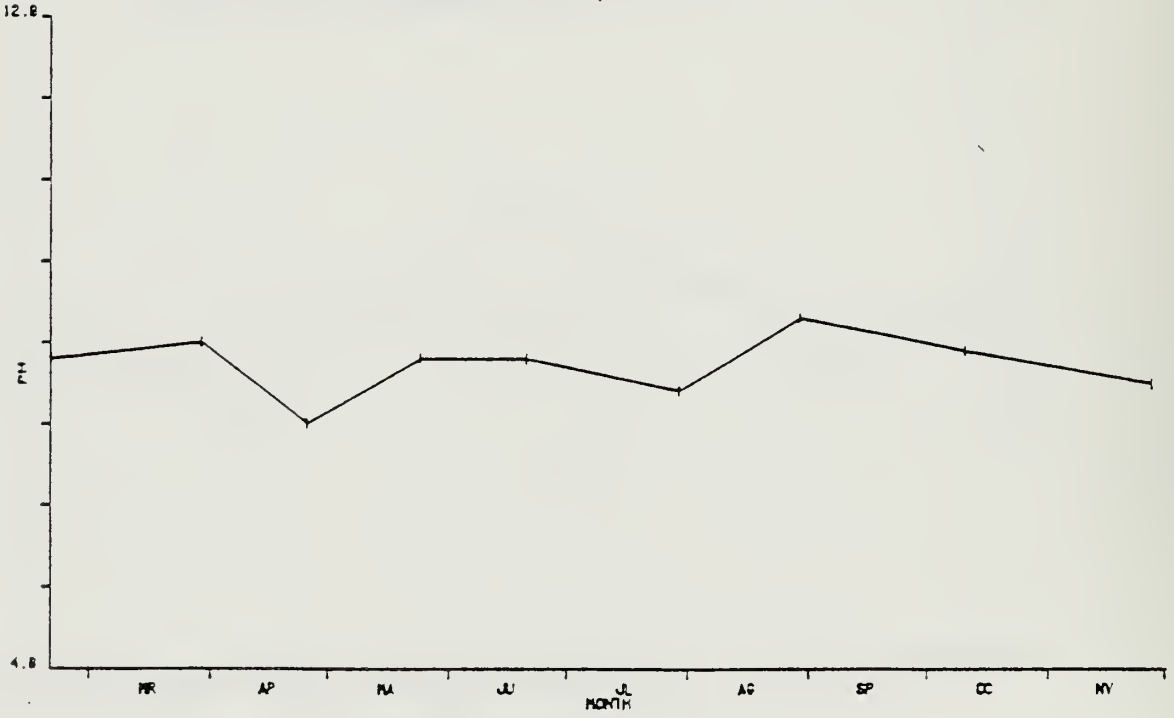

Figure 5-113

Lower aquifer wells - The hydrograph for CE-702 lower is shown in Figure 5-114. The water level in this well is relatively stable until mid-September, at which time it begins to increase.

The hydrograph for CE-709 lower is shown in Figure 5-115. Except for one anomalous reading in September, the water levels in this hole are relatively stable. The anomalous reading may have been a measurement error.

The hydrograph for D-17 is shown on Figure 5-116. Water levels in this hole remain relatively constant throughout the reporting period.

The hydrograph for G-S 4-5 lower is shown in Figure 5-117. The water level in this hole decreases slightly until September, when it begins to increase slightly.

Physical data for G-S 15 lower are plotted in Figures 5-118 through 5-121. The hydrograph for this hole indicates a slight, though insignificant decline over the reporting period. During the last three months of the reporting period, however, there appears to be a slight rise in water level. Conductivity for G-S 15 lower shows a dramatic rise from the beginning of the reporting period through April then a similar decline from April through July. The explanation for this high variability in conductivity is attributed to the presence of upper aquifer water in the lower aquifer. Temperature and pH fluctuate.

Physical data for TO-1 are plotted in Figures 5-122 through 5-125. The hydrograph for this hole shows a decline from June through September, followed by a rise for the remainder of the reporting period. The conductivity, temperature, and pH data were insufficient for interpretation.

CE-702 LOWER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

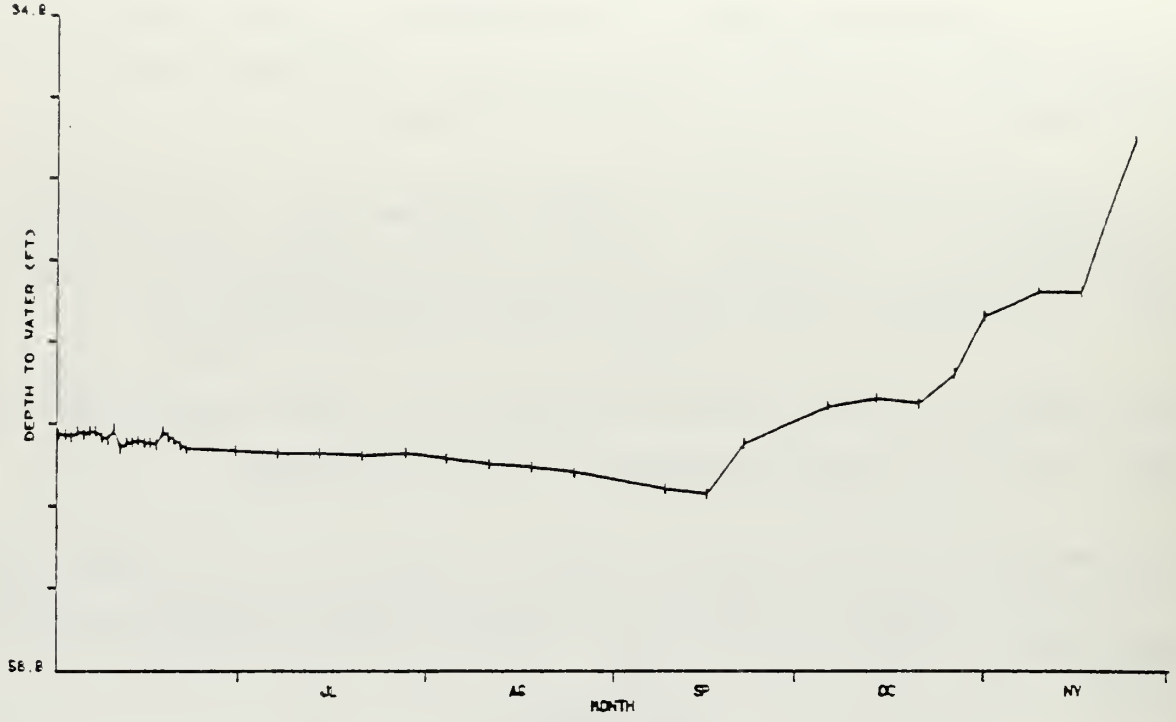

Figure 5-114

CE-709 LOWER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

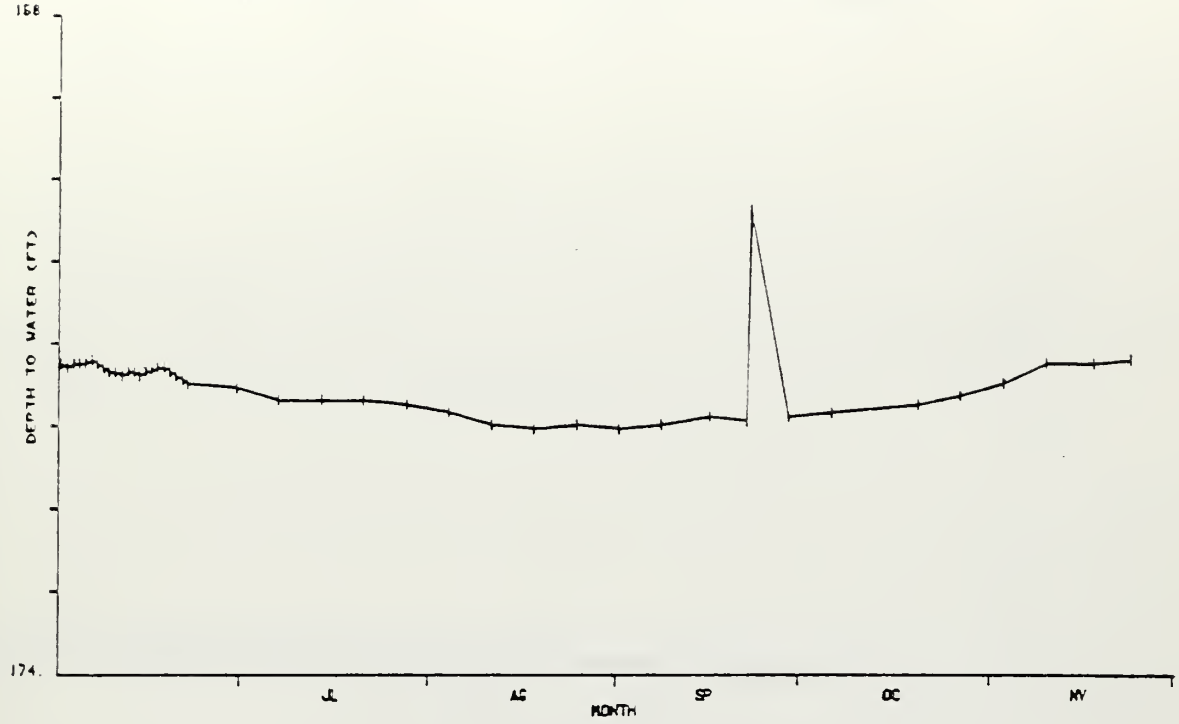

Figure 5-115

D-17 HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

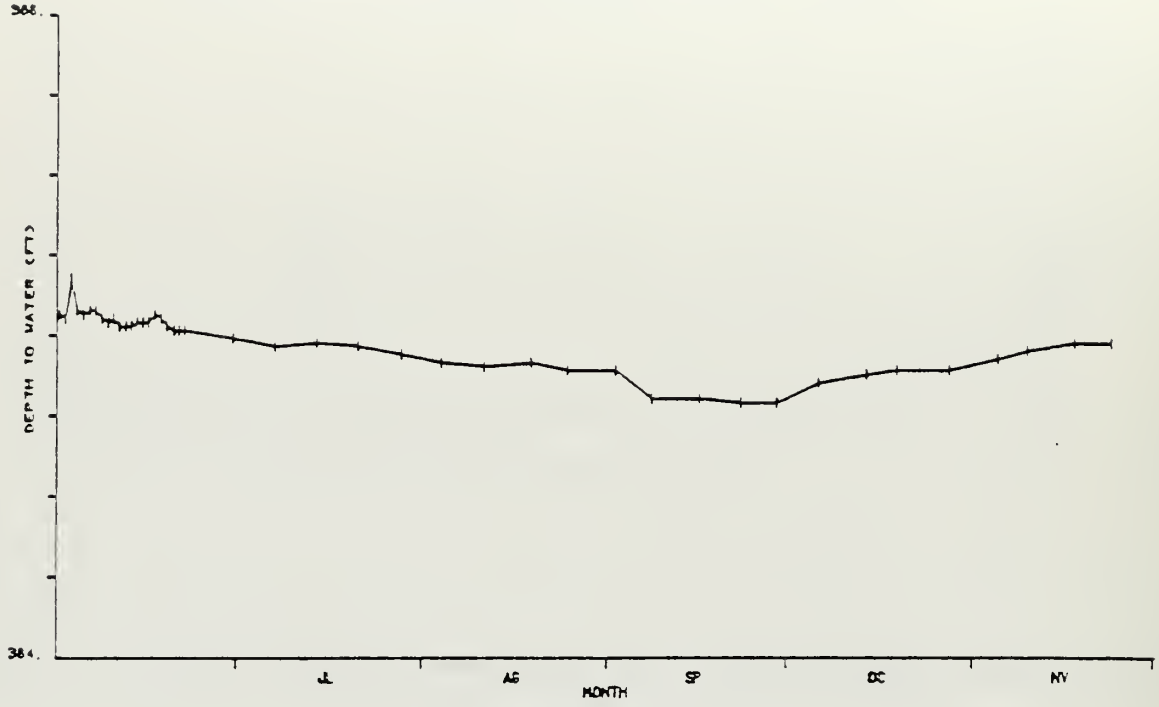

Figure 5-116

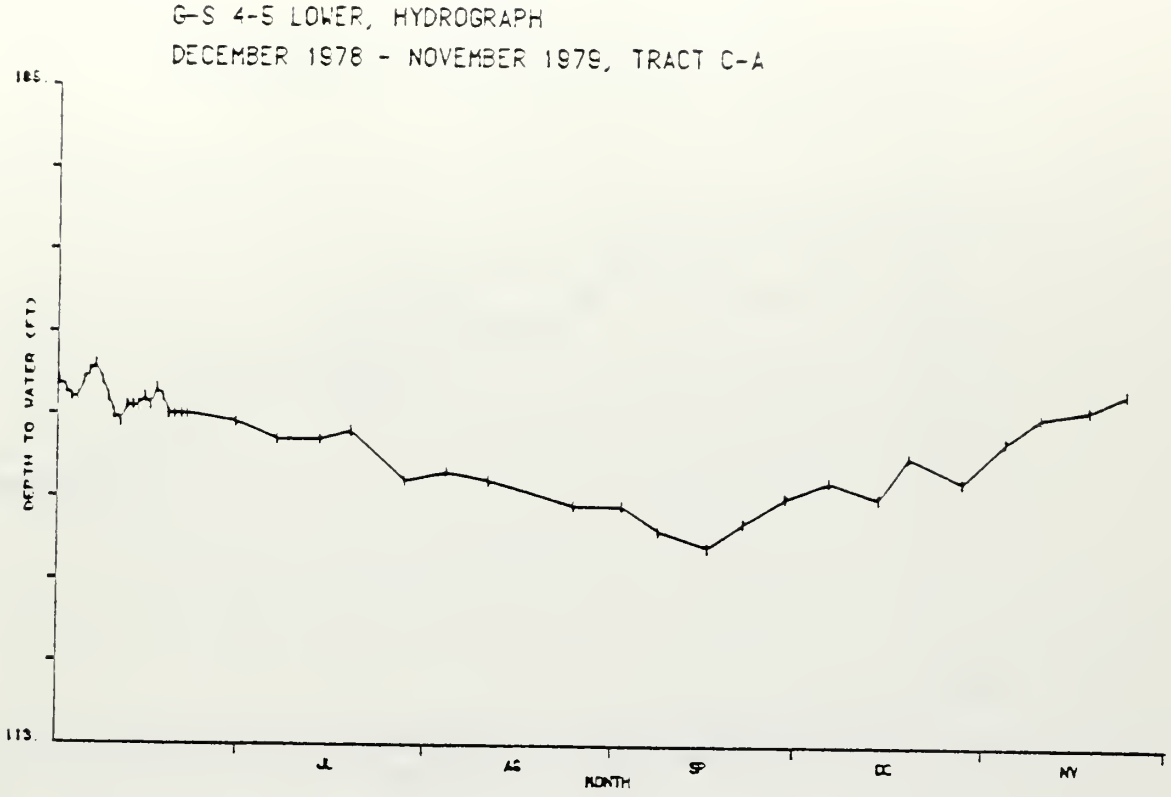
G-S 4-5 LOWER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A
185.
113.
DEPTH TO WATER (FT)
JL
AG
SP
OC
NV
MONTH

Figure 5-117

G-S 15 LOWER, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

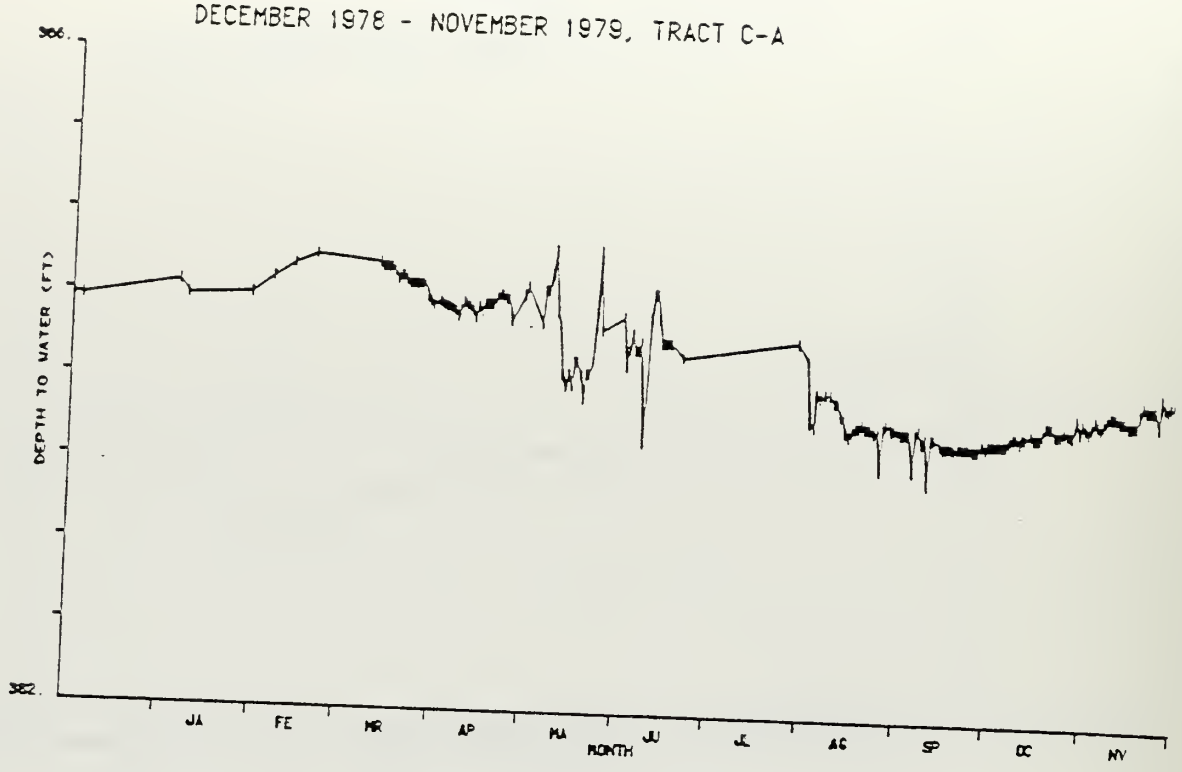

Figure 5-118

G-S 15 LOWER, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

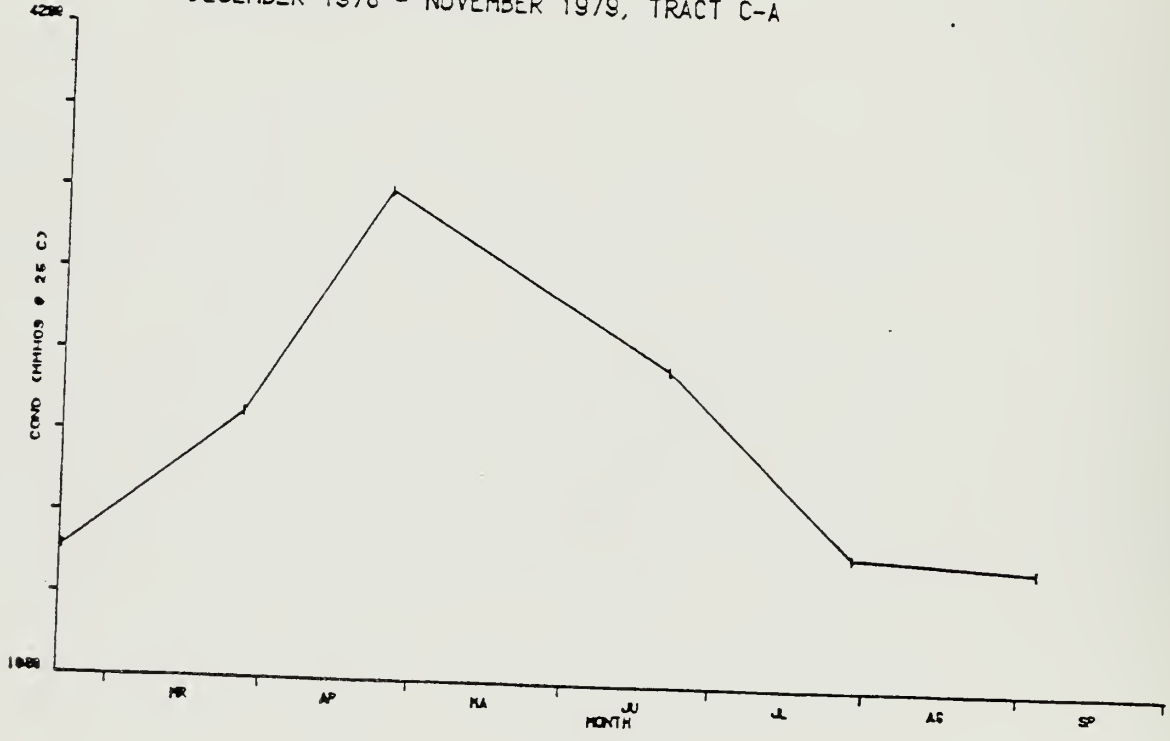

Figure 5-119

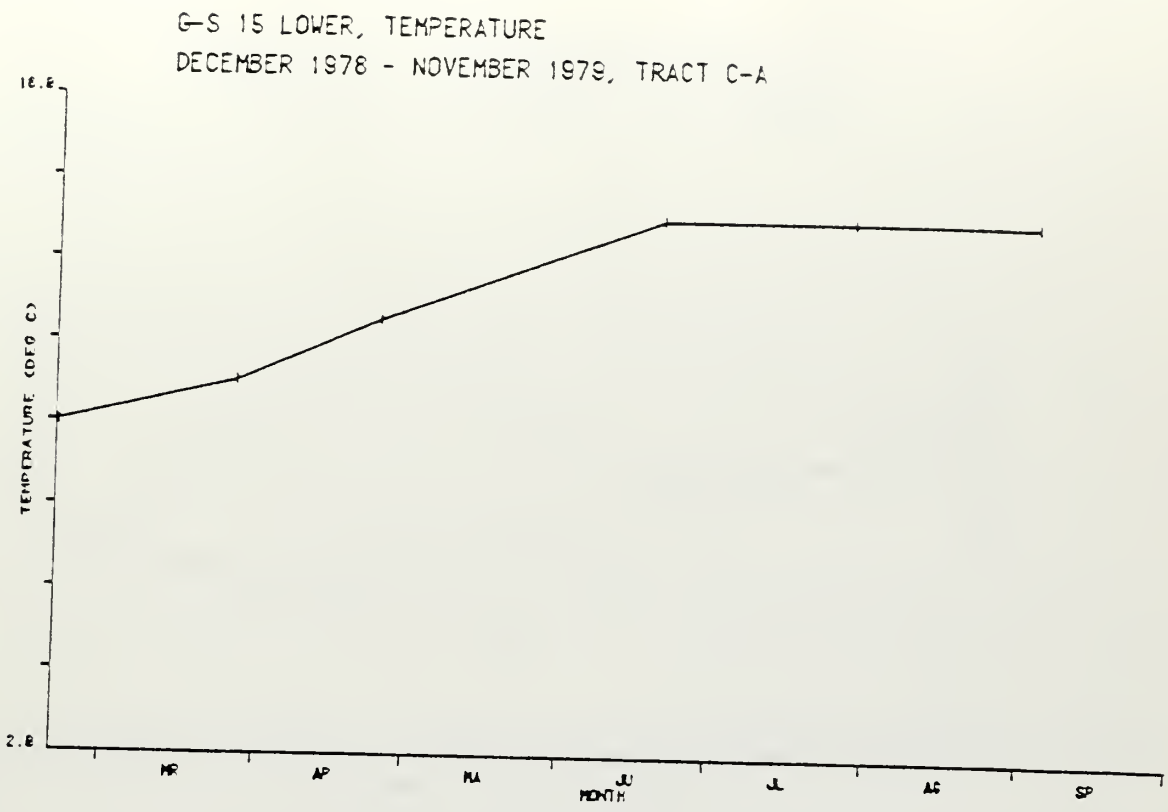

Figure 5-120

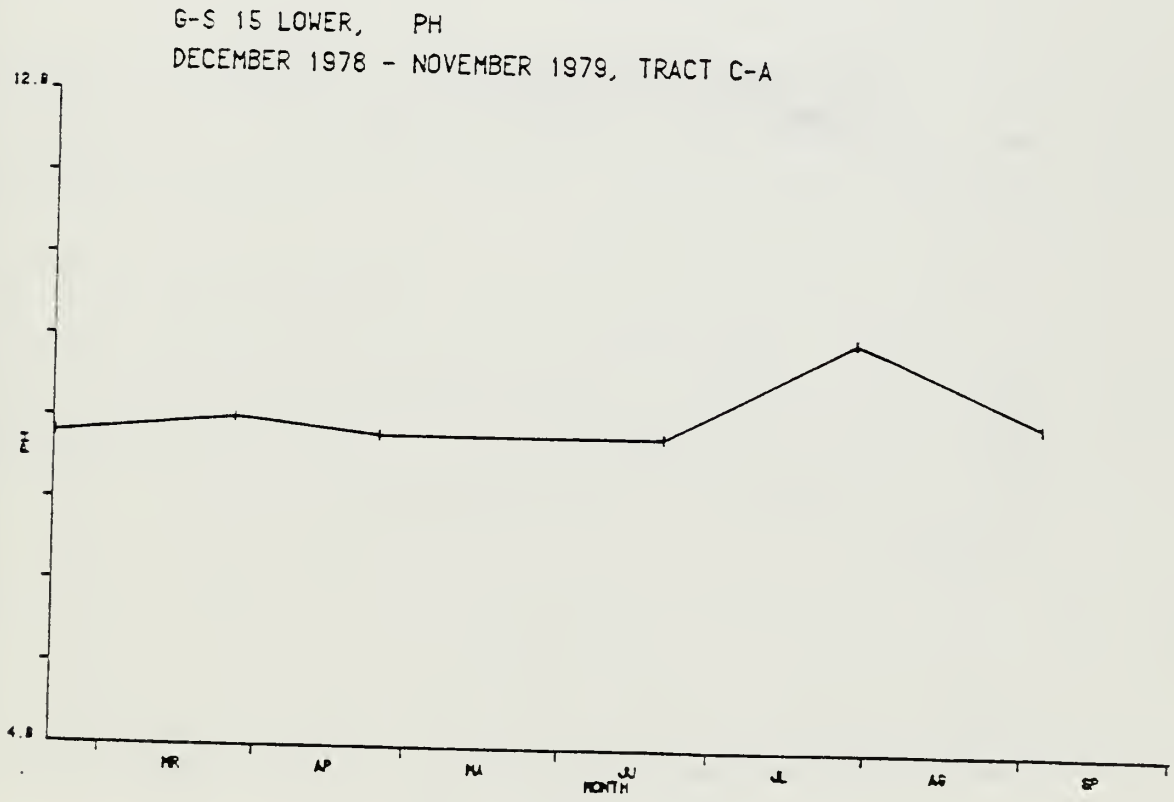

Figure 5-121

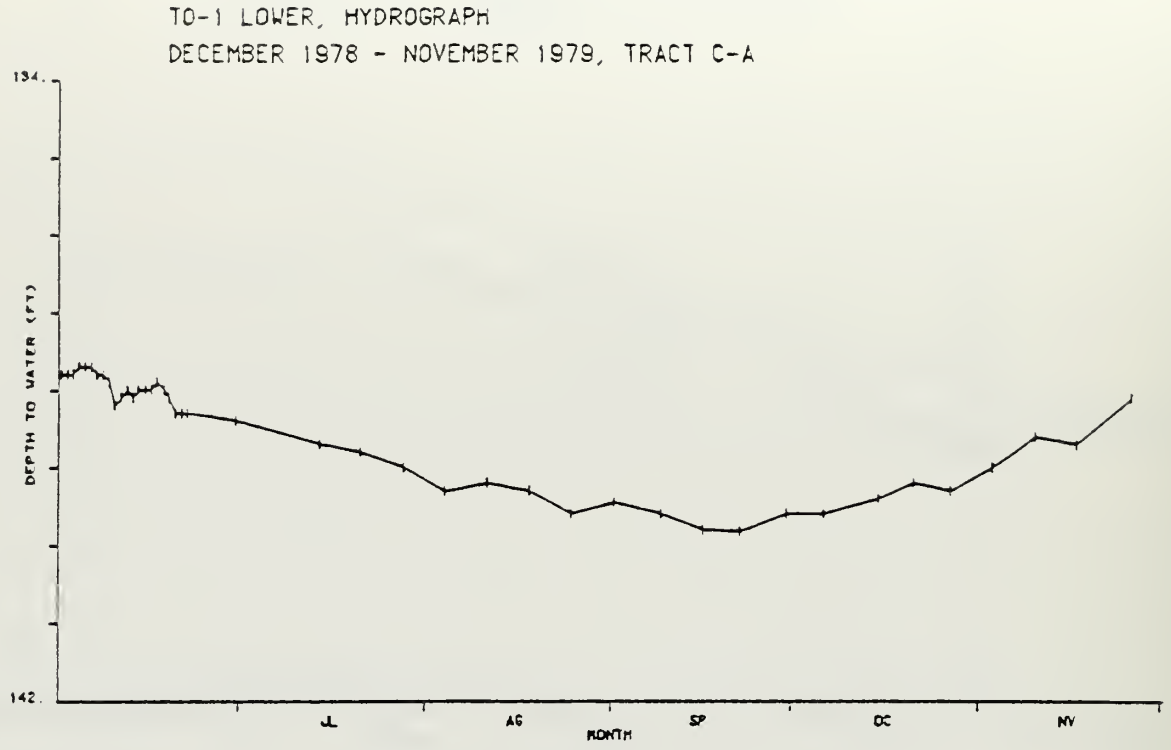

Figure 5-122

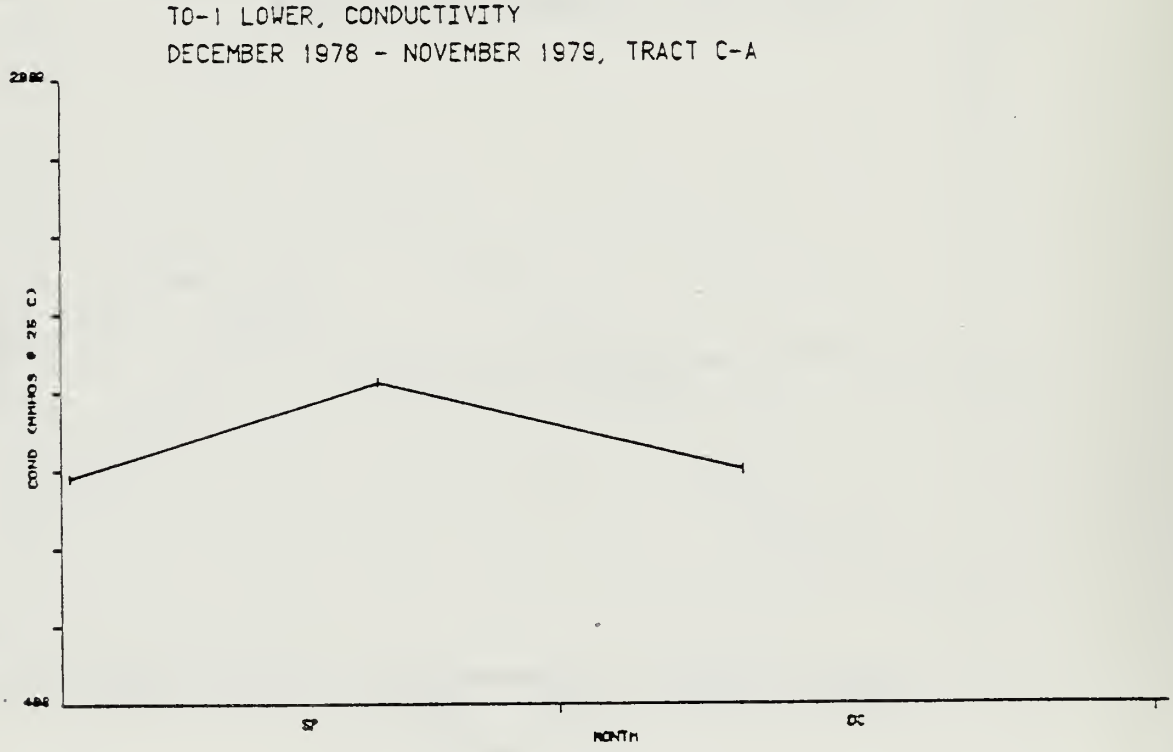

Figure 5-123

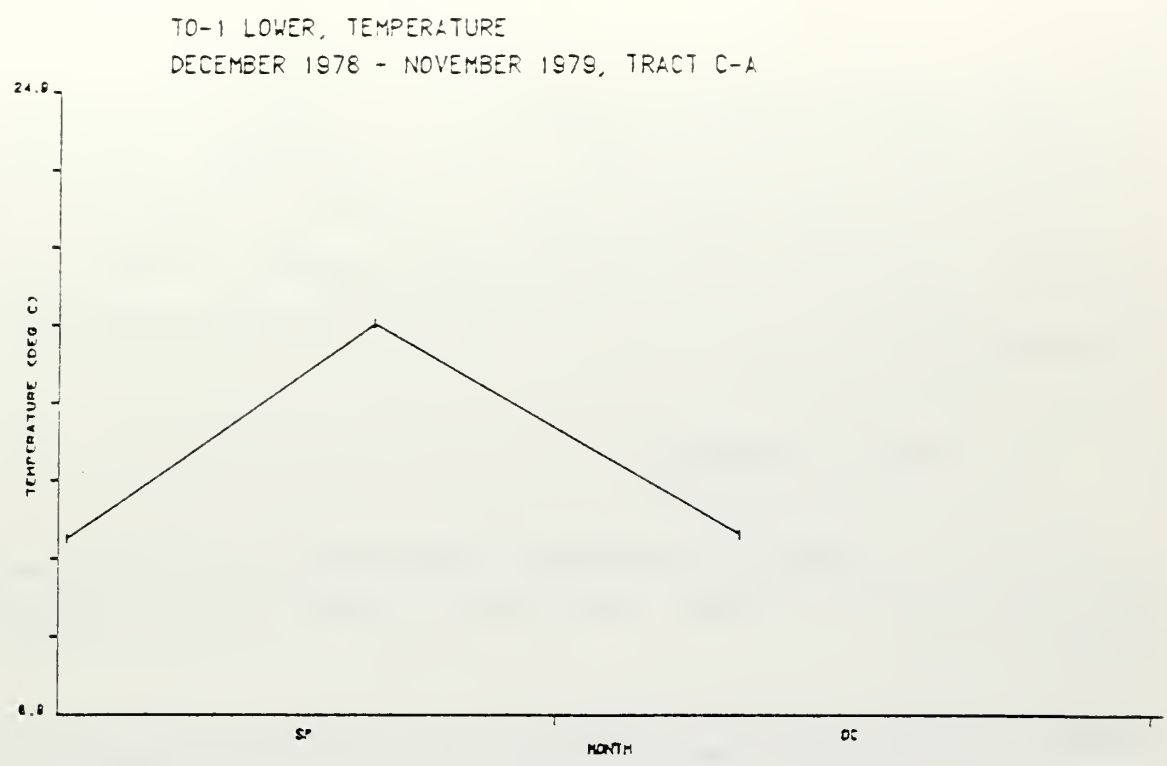

Figure 5-124

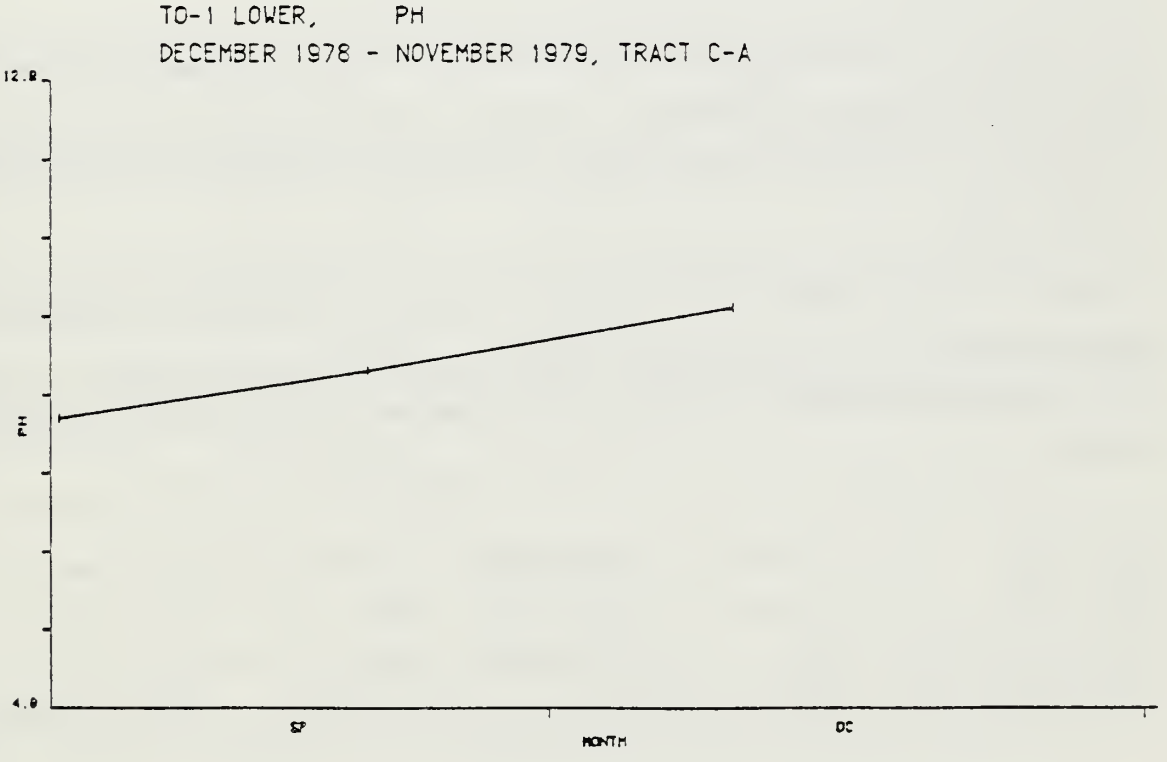

Figure 5-125

The water levels in the lower aquifer have not responded significantly to dewatering; however, since September, a few of them appear to have responded to reinjection in the northeast corner of the Tract. Conductivity fluctuations are attributed to the presence of small amounts of upper aquifer water near the boreholes that entered the lower aquifer before bridges were placed in-between the aquifers.

b. Chemical parameters

Statistical analyses - Water quality data collected during the reporting period December 1978 through November 1979 are presented in Appendix 5-2.3.

Summary statistics for these individual data stations are presented in Appendix 5-2.4. A statistical summary of the reporting period data for six upper aquifer stations and for one lower aquifer station are provided in Tables 5-19 and 5-20, respectively.

The results of the comparison of baseline with reporting period observed maximum concentrations, differences in means, and comparison of water quality composition for the upper and lower aquifers are reported in Tables 5-21 through 5-24.

The data listed in Table 5-21 show that only a few constituents measured during the reporting period exceeded baseline maximum concentrations. The constituents show relatively small increases over the baseline maximum observations.

Statistical testing included the comparison of baseline mean concentrations with means of various reporting period data sets (Table 5-22, Appendix 5-2.5). These analyses shown are slightly higher by specific conductance and TDS concentration in the upper aquifer relative to the baseline. Contributions to

STATION: '79 Upper OS Aquifer 49 samplings

Parameter	Obs.	Min	Max	Mean	St Dev	95% Conf Inter		Traces
ALUMINUM	10	0.100	0.550	0.154	1.213	0.079	0.316	6
AMMONIA	4	0.100	1.300	0.207	3.444	0.003	13.370	1
ARSENIC	10	0.010	0.050	0.016	2.176	0.007	0.038	10
BICARBONATE	27	220.000	716.000	420.234	1.347	416.024	376.572	0
CADMIUM	10	0.010	0.010	0.010	1.000	0.010	0.010	10
CALCIUM	43	4.200	157.000	32.240	2.526	27.203	56.417	0
CARBONATE	24	0.100	130.000	4.333	17.613	0.809	23.225	8
CHLORIDE	43	2.000	63.000	15.017	1.769	12.007	18.782	0
CHROMIUM	10	0.010	0.010	0.010	1.000	0.010	0.010	10
COPPER	0	0.000	0.000	0.000	0.000	0.000	0.000	0
FLUORIDE	48	0.070	1.650	0.331	2.380	0.254	0.597	7
HYDROXIDE	2	0.100	94.000	3.066	126.567	0.000	0.000	0
IRON	15	0.050	2.500	0.111	3.147	0.044	0.275	9
LEAD	10	0.010	0.040	0.020	1.844	0.010	0.038	4
MAGNESIUM	48	17.000	184.000	74.917	1.846	58.908	95.277	0
MERCURY	10	0.001	0.001	0.001	1.000	0.001	0.001	10
NITRATE	12	0.010	3.000	0.168	5.400	0.035	0.814	1
PHOSPHATE	10	0.100	0.120	0.102	1.052	0.036	0.109	9
POTASSIUM	17	0.200	4.500	1.943	2.067	1.144	3.301	0
SELENIUM	10	0.010	0.010	0.010	1.000	0.010	0.010	10
SILICON DIOXIDE	43	0.100	42.750	12.541	3.163	7.978	19.713	2
SODIUM	43	2.250	390.000	212.224	2.014	161.257	279.306	0
SULFATE	43	6.250	1063.000	417.661	2.223	305.015	571.909	0
SULFIDE	10	0.020	0.310	0.123	2.705	0.042	0.362	9
ZINC	10	0.020	0.500	0.104	2.812	0.034	0.320	3
RADIO. GROSS ALPHA	3	0.100	1.800	0.660	5.134	0.000633	13.426	0
RADIO. GROSS BETA	4	3.000	44.000	14.555	3.101	0.320	661.716	0
HARDNESS, TOTAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
PH	37	7.000	8.900	7.927	0.436	7.723	8.125	0
CONDUCTANCE, SPEC.	28	930.000	2500.000	1550.543	1.295	1350.973	1779.715	0
SOLIDS, TOT. DISS.	19	742.000	2450.000	1230.235	1.415	845.201	1792.713	0
MANGANESE	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ALKALINITY	46	285.000	586.000	416.022	1.212	385.183	443.452	0
CYANIDE	10	0.010	0.010	0.010	1.000	0.010	0.010	10
BORON	13	0.040	0.300	0.130	1.705	0.095	0.177	5
BARIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
SILVER	1	0.010	0.010	0.010	0.000	0.000	0.000	1
NICKEL	6	0.010	0.010	0.010	1.000	0.010	0.010	6
LITHIUM	1	2.000	2.000	2.000	0.000	0.000	0.000	0
ORG. CARBON, DISS.	8	2.000	18.000	5.386	2.027	2.036	14.252	0
NITRITE-N	7	0.010	0.109	0.027	3.424	0.004	0.173	7
BROMIDE	7	0.100	0.150	0.106	1.146	0.084	0.134	6
COD	10	2.500	23.000	10.953	2.140	4.804	24.968	0
PHENOLS	10	0.001	0.040	0.002	4.403	0.000	0.012	7
KJELDAHL N	0	0.000	0.000	0.000	0.000	0.000	0.000	0
BERYLLIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
MOLYBDENUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
STRONTIUM	10	0.300	2.700	1.350	2.173	0.523	2.814	0
VANADIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
PHOSPHATE, ORTHO	0	0.000	0.000	0.000	0.000	0.000	0.000	0
NITROGEN, AMMONIA	7	0.100	1.400	0.402	3.458	0.063	2.675	1
TEMPERATURE	45	7.500	19.500	11.763	2.700	10.472	12.844	0
MBAS	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, TOTAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, FECAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0

Table 5-19

STATION: GS-151 (779) 7 samplings

Parameter	Obs.	Min	Max	Mean	St Dev	99% Conf Inter		Traces
ALUMINUM	2	0.100	0.300	0.173	2.173	0.000	0.000	1
AMMONIA	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ARSENIC	2	0.010	0.050	0.022	3.121	0.000	0.000	2
BICARBONATE	5	547.000	1700.000	1307.255	1.430	424.327	4027.355	0
CADMIUM	2	0.010	0.010	0.010	1.000	0.010	0.010	2
CALCIUM	7	2.500	9.800	4.476	1.502	2.237	8.958	0
CARBONATE	5	4.240	112.000	38.166	3.546	2.071	703.209	0
CHLORIDE	7	2.100	53.000	16.386	3.467	2.496	107.575	0
CHROMIUM	2	0.010	0.010	0.010	1.000	0.010	0.010	2
COPPER	0	0.000	0.000	0.000	0.000	0.000	0.000	0
FLUORIDE	7	5.400	55.500	21.733	2.411	5.754	82.507	0
HYDROXIDE	0	0.000	0.000	0.000	0.000	0.000	0.000	0
IRON	4	0.005	0.077	0.031	3.456	0.000	2.051	2
LEAD	2	0.010	0.020	0.014	1.633	0.000	0.000	1
MAGNESIUM	7	23.000	73.000	50.022	1.477	27.724	90.253	0
MERCURY	2	0.001	0.001	0.001	1.000	0.001	0.001	2
NITRATE	4	0.002	1.800	0.699	10.129	0.000	244.278	0
PHOSPHATE	2	0.400	1.600	0.800	2.665	0.000	0.000	1
POTASSIUM	4	2.000	6.500	3.697	1.623	0.723	18.921	0
SELENIUM	2	0.010	0.010	0.010	1.000	0.010	0.010	2
SILICON DIOXIDE	7	2.000	20.000	4.293	2.138	1.577	15.757	0
SODIUM	7	310.000	770.000	533.243	1.416	318.458	913.133	0
SULFATE	7	87.500	410.000	257.025	1.636	115.583	571.787	0
SULFIDE	2	0.020	0.200	0.063	5.035	0.000	0.000	2
ZINC	2	0.050	0.100	0.071	1.633	0.000	0.000	1
RADIO. GROSS ALPHA	0	0.000	0.000	0.000	0.000	0.000	0.000	0
RADIO. GROSS BETA	1	73.000	73.000	73.000	0.000	0.000	0.000	0
HARDNESS, TOTAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
PH	2	8.400	9.000	8.700	0.424	-10.303	35.703	0
CONDUCTANCE, SPEC.	5	1625.000	3400.000	2204.524	1.410	1044.343	5095.333	0
SOLIDS, TOT. DISS.	2	1170.000	2100.000	1547.493	1.512	0.000	0.000	0
MANGANESE	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ALKALINITY	7	542.000	1400.000	1001.138	1.439	542.292	1845.851	0
CYANIDE	2	0.010	0.010	0.010	1.000	0.010	0.010	2
BORON	3	0.540	1.600	0.952	1.724	0.021	43.564	0
BARIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
SILVER	0	0.000	0.000	0.000	0.000	0.000	0.000	0
NICKEL	1	0.010	0.010	0.010	0.000	0.000	0.000	1
LITHIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
ORG. CARBON, DISS.	1	7.000	7.000	7.000	0.000	0.000	0.000	0
NITRITE-N	1	0.010	0.010	0.010	0.000	0.000	0.000	1
BROMIDE	2	0.100	0.100	0.100	1.000	0.100	0.100	2
COD	2	20.000	35.000	24.438	1.405	0.000	0.000	0
PHENOLS	2	0.001	0.030	0.005	11.073	0.000	0.000	1
KJELDAHL N	0	0.000	0.000	0.000	0.000	0.000	0.000	0
BERYLLIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
MOLYBDENUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
STRONTIUM	2	0.100	0.250	0.138	1.312	0.000	0.000	0
VANADIUM	0	0.000	0.000	0.000	0.000	0.000	0.000	0
PHOSPHATE, ORTHO	0	0.000	0.000	0.000	0.000	0.000	0.000	0
NITROGEN, AMMONIA	2	0.100	1.400	0.374	4.443	0.000	0.000	1
TEMPERATURE	4	10.000	15.000	12.125	2.173	4.721	13.453	0
MBAS	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, TOTAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0
COLIFORM, FECAL	0	0.000	0.000	0.000	0.000	0.000	0.000	0

this change are slight increases of magnesium, carbonate, bicarbonate, sulfate, and chloride (when reporting period data lumped) and possibly increases of sodium and calcium at several individual wells (G-S M3, G-S M4, and G-S 15U). Upper aquifer pH was higher during the reporting period than during the baseline data set.

Numerous trace constituents were also different from baseline mean concentrations. However, the mean concentrations for the reporting period were generally lower than baseline means. This pattern of decreased concentration was observed for boron, aluminum, chromium, iron, lead, mercury, nickel, strontium, zinc, and sulfide. Mean concentration of bromide increased over baseline mean concentrations.

Table 5-21. Water Quality Constituents for Which the Maximum Observed Concentration for the Report Period Exceeded the Maximum for the Baseline Period, Upper and Lower Oil Shale Aquifers

Aquifer	Constituent	Maximum Observed Concentration	
		Baseline Period	Report Period
Upper	Sulfate	900	1063
	pH	8.8	8.9
	Lithium	1.0	2.0
Lower	pH	8.9	9.0

Table 5-22. Results of Statistical (t, F and t') Test Comparison of Baseline and MDF Means for Upper and Lower Aquifer Water. Constituents Listed are Those for Which the Null Hypothesis of Equality of Means was Rejected

	Station or Stations Compared to Baseline							
	Upper Aquifer							Lower Aquifer
Constituent	All Wells[1]	AM-3	G-S M 1	G-S M 2	G-S M 3	G-S M 4	G-S 15 U	G-S 15L
Sp. Conductance	>[2]			>	>	>	>	>
TDS	>			>		>	>	
pH	>	>	>	>	>	>	>	>
Alkalinity		<	<			>		
Temperature		<			<			>
Sodium					>		>	>
Calcium					<	>	>	<
Magnesium	>		<			>	>	>
Carbonate	>	>			>			
Bicarbonate			<		<	>	>	
Sulfate	>	<		>			>	>
Chloride	>				>			
Fluoride		>	<		>	<		
Silicon Dioxide	<	<		<	<			<
Boron	<		<	<		<		
Aluminum				<	>	<		
Bromide	>				>		>	>
Chromium	<			<	<	<	<	<
Iron	<		<	<	<	<	<	<
Lead	<			<	<	<	<	<
Mercury	<			<	<	<	<	<
Nickel	<							
Strontium	<					<		<
Zinc	<			<			<	<
Sulfide	<			<	<	<	<	
Ammonia-N					<			
Phenols					<			
COD								>

[1] Means of all upper aquifer wells in environmental monitoring program compared to baseline upper aquifer mean concentrations.

[2] > and < symbols indicate test results showing difference in means of baseline and report period; < indicates that report period mean is less than baseline; > indicates report period mean greater than baseline.

[3] Blank in table indicates that means tested not different.

Table 5-23. Spearman Rank-Order Correlation Analysis of Upper Aquifer Baseline and Reporting Period Means of Major Inorganic Ions

Constituent	Baseline Period			Report Period		
	Mean (mg/l)	Mean (meq/l)*	Rank	Mean (mg/l)	Mean (meq/l)*	Rank
Sodium	212.0	9.22	1	212.2	9.23	1
Calcium	34.8	1.74	5	39.2	1.96	5
Magnesium	51.5	4.22	4	74.9	6.14	4
Potassium	2.2	0.05	7	1.9	0.05	8
Chloride	12.0	0.34	6	15.0	0.42	6
Carbonate	0.9	0.03	8	4.3	0.14	7
Bicarbonate	482.0	7.90	2	490.2	8.04	3
Sulfate	325.0	6.77	3	417.6	8.70	2

Spearman's Coefficient (r_s) = 0.953

$\sum d = 0$: $\sum d^2 = 0$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

Table 5-24. Spearman Rank-Order Correlation Analysis of Lower Aquifer Baseline and Reporting Period Means of Major Inorganic Ions

Constituent	Baseline Period			Report Period		
	Mean (mg/l)	Mean (meq/l)*	Rank	Mean (mg/l)	Mean (meq/l)*	Rank
Sodium	397.0	17.26	1	539.3	23.45	1
Calcium	8.8	0.44	7	4.5	0.23	7
Magnesium	20.0	1.64	5	50.0	4.10	4
Potassium	2.6	0.07	8	3.7	0.10	8
Chloride	21.7	0.61	6	16.4	0.46	6
Carbonate	68.8	2.29	4	38.2	1.27	5
Bicarbonate	842.0	13.80	2	1307.3	21.43	2
Sulfate	112.0	2.33	3	257.1	5.36	3

Spearman's Coefficient (r_s) = 0.976

$\sum d = 0$: $\sum d^2 = 0$: $n = 8$

$$r_s = 1 - \frac{6 \sum d^2}{n (n^2-1)}$$

where d = difference in rank order for same constituent between two samples

n = number of constituents in sample

note: to use this method $\sum d$ must be equal to zero

* meq/l = mg/l ÷ equivalent mass

(equivalent mass = atomic weight ÷ valance)

Statistical testing included comparison of baseline mean concentrations with means of various report period data sets (Table 5-22, Appendix 5-2.5). These analyses show an increase in salinity (as measured by specific conductance and TDS concentration) in the upper aquifer relative to the baseline. Contribution to this increase are increases of magnesium, carbonate, bicarbonate, sulfate and chloride (when report period data lumped) and possibly increases of sodium and calcium at several individual wells (G-S M3, G-S M4, and G-S 15U). Upper aquifer pH was also increased during the report period relative to the baseline data set.

Numerous trace constituents were also different from baseline mean concentrations. However, the mean concentrations for the report period were generally lower than baseline means. This pattern of decreased concentration was observed for boron, aluminum, chromium, iron, lead, mercury, nickel, strontium, zinc and sulfide. Bromide mean concentration was increased over baseline observations.

Lower aquifer data for the report period (as shown by well G-S 15L data) also included changes relative to baseline mean levels. The increase in specific conductance (Table 5-22) was accompanied by increases in mean concentrations of sodium, magnesium, and sulfate. Calcium concentration decreased relative to the baseline. As was observed in the upper aquifer, mean bromide levels were greater during the report period while other trace constituents (chromium, iron, lead, mercury, strontium, and zinc) decreased. Chemical oxygen demand (COD) was significantly higher in the lower aquifer.

To test changes in general water quality composition of upper and lower aquifers, the concentrations of major inorganic constituents were evaluated by estimation of the Spearman rank-order correlation coefficient (Tables 5-23 and 5-24). These analyses indicate that the relative levels of the major inorganic ions observed during the report period were not different from baseline levels.

A special study of the spatial and temporal variation in deep aquifer water quality for the reporting period is presented in Appendix 5-2.11 with Figures 5-126 through 5-160.

5.3 DEVELOPMENT ACTIVITIES MONITORING

1. Objectives

The objective of the development activities monitoring program is to determine the direct impacts of specific activities associated with the oil shale development on Tract C-a. The monitoring stations associated with this program have been installed as needed, when a particular activity, such as dewatering, commenced. The development activities monitoring stations are located on-tract, in the vicinity of or downstream from development activities. A location of these monitoring stations is shown in Map 1 (see Map pocket).

2. Methods

The development activities which are being monitored as part of this program are all associated with the dewatering of the oil shale aquifer. The Surface Induced Recharge (SIR) testing was conducted to determine the feasibility of recharging dewatering water back to the upper aquifer through the alluvium of "SIR" Gulch. As part of this program, five flumes located in a series downstream from the discharge point were monitored to determine losses to or gains from the alluvium. Twelve alluvial wells were drilled to monitor the impact on the water table in the alluvium of the recharge. In both the flumes and the alluvial wells, water samples were collected for determination of impact of the recharging on the physical parameters (pH, conductivity, temperature). One well was drilled and monitored to determine chemical, physical, and water level impacts of the SIR Gulch recharge activity at depth. Stream channel erosion was also monitored at a series of six stations downstream from the discharge point.

The functional dewatering wells were monitored for flow, physical, and chemical characteristics. The holding ponds for the dewatering water were also

monitored for physical and chemical characteristics. Four piezometers were installed to detect any seepage from the East Retention Pond. Water levels were detected in only three of these and those water levels appeared after heavy rains and disappeared a few days later.

There are four reinjection wells; G-S 4-5, G-S 6, TO-2, and TO-3 of which TO-2 was put on standby to reduce recycling to the mine. Physical and chemical parameters are analyzed for samples taken from these wells during the reinjection period. In addition, two springs are monitored to detect any possible impacts on surface water due to the reinjection. One of these springs, Box Elder flume, is located immediately upstream from Miller Spring, the other, which is located between Station D and the road. Water levels are measured in these springs, and physical parameters are determined from samples taken from them.

Water that is not reinjected or recharged is discharged. A series of seven surface monitoring stations are located downstream from the discharge point. Water levels are measured in these and physical parameters are determined from samples taken at each point.

3. Results and Discussion

a. Surface Induced Recharge Program (SIR) - The results of the flow monitoring program for SIR Gulch are shown graphically in Figure 5-161. The results are presented in the form of flow profiles at each of several dates, rather than as hydrographs at the individual stations, to better illustrate the progress of the recharge program. During the early part of the program (June 23 through June 29) the flow profile showed a consistent decline in flow rate, indicating a substantial rate of saturation of the alluvium. During subsequent monitoring periods, the apparent rate of saturation decreased, as indicated by an increase in stream flow. Increases in flow rate were recorded at Flumes No. 1 and 4. The behavior of the data was also influenced

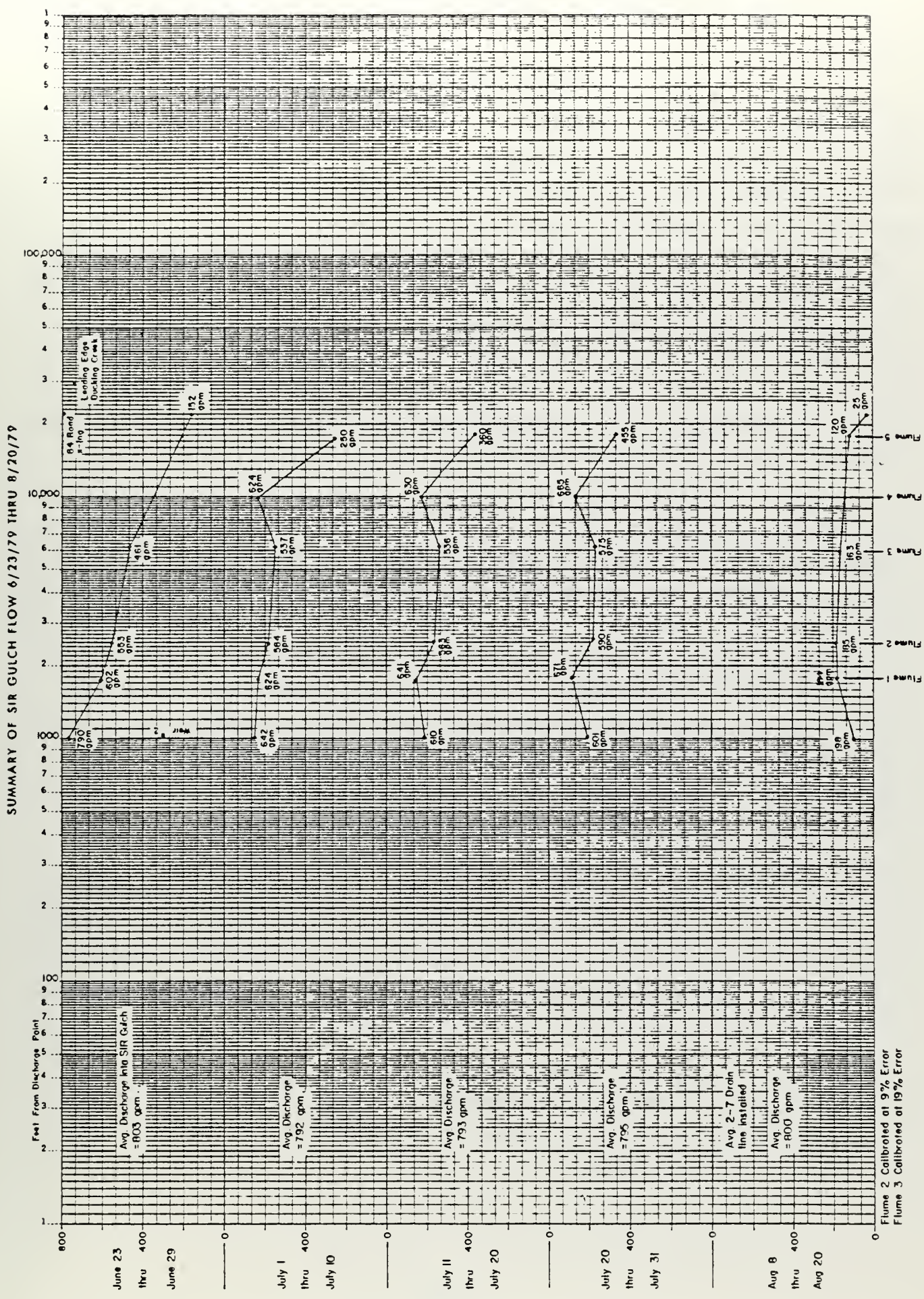
SUMMARY OF SIR GULCH FLOW 6/23/79 THRU 8/20/79
Average Discharge/GPM
Feet From Discharge Point
84 Road
Leading Edge
Ducking Creek
Flume 1
Flume 2
Flume 3
Flume 4
Flume 5
June 23 thru June 29
July 1 thru July 10
July 11 thru July 20
July 20 thru July 31
Aug 8 thru Aug 20
Avg. Discharge into SIR Gulch = 803 gpm
Avg. Discharge = 792 gpm
Avg. Discharge = 793 gpm
Avg. Discharge = 795 gpm
Avg 2-7 Drain line installed
Avg. Discharge = 800 gpm
Flume 2 Calibrated at 9% Error
Flume 3 Calibrated at 19% Error

Figure 5-161.

by the natural seasonal fluctuation in the groundwater table in the alluvium. SIR Gulch Deep Well #1, installed as a part of the SIR Gulch program, encountered a perched water table above the upper aquifer. Water in this perched water table has subsequently receeded and this deep well is now dry. Small increase in water level in the upper aquifer Well M-4 indicated that some recharge occurred to the upper aquifer during this time. How much was SIR Gulch recharge as opposed to natural recharge is not known since increases in the upper aquifer water levels also occurred in other areas west of the mining operations. The results of the SIR Gulch test indicate that while water spread on the surface locally recharges the alluvium, it is not an effective method of recharging the upper aquifer at the site chosen for the test.

Conductivity, temperature, and pH are plotted for each of the SIR Gulch monitoring stations in Figures 5-162 through 5-170. In Flumes No. 1, 2, and 3, the physical parameters are considered representative of the water being discharged. Temperature fluctuations seen in these plots vary by a few degrees, and are not in a definite pattern. Fluctuations such as these are normal considering the exposure of the discharge water to normal climatic temperature fluctuations. Plots of pH for these three stations indicate little variation in water quality. Fluctuations in conductivity generally indicate two factors: 1) the quality of the discharge water, and 2) the leaching of salts from the banks of the stream. During the month of July, a significant increase in conductivity was recorded; this increase was most noticeable in Flume No. 1. At this time, the mode of operation of the Surface Induced Recharge program was altered, and the discharge was spread over an area rather than being discharged into the stream at one point. The increase in conductivity at this time is attributed to leaching of salt from the soils in the area where the spreading took place.

Physical data for Flume No. 4 are recorded in Figures 5-171 through 5-173. The available data indicate that Flume No. 4 is very similar to Flume 5 for which more data is available.

FLUME #1 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

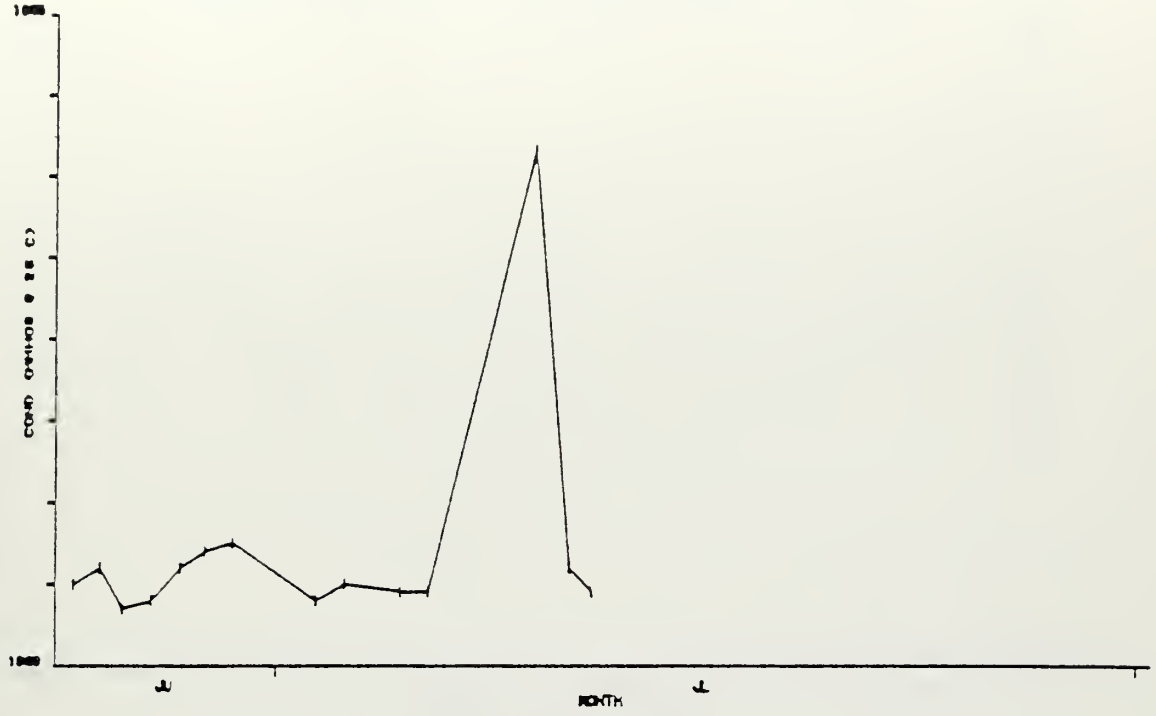

Figure 5-162

FLUME #1 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

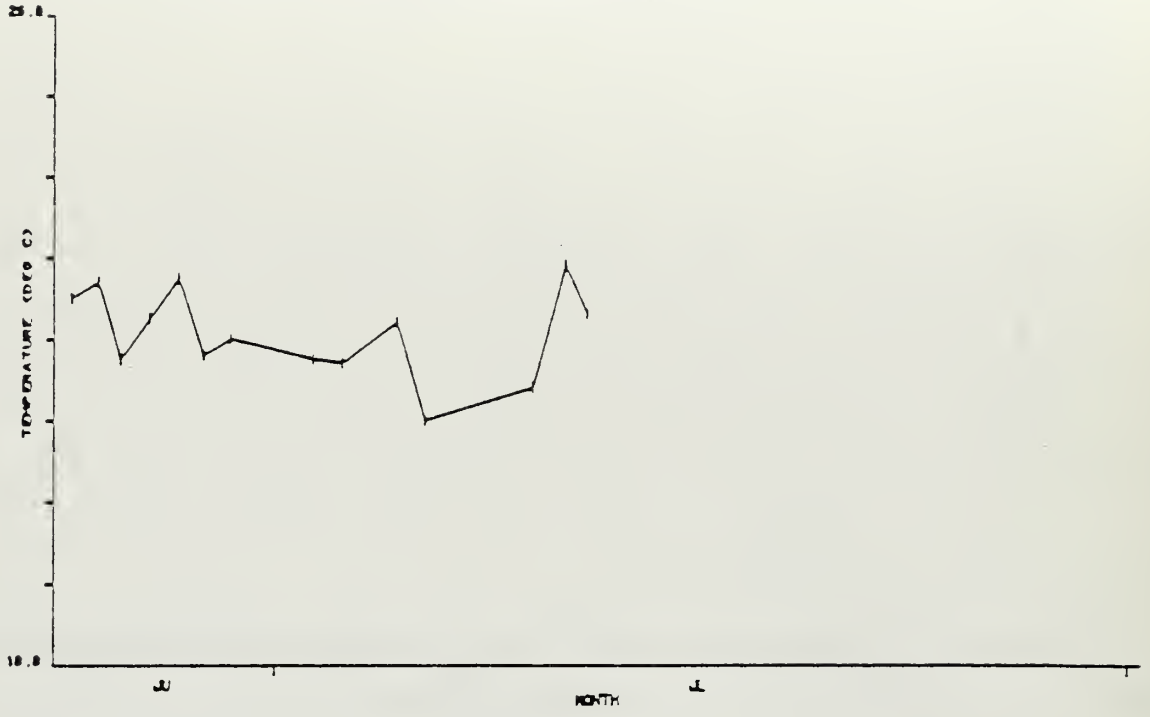

Figure 5-163

FLUME #1 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

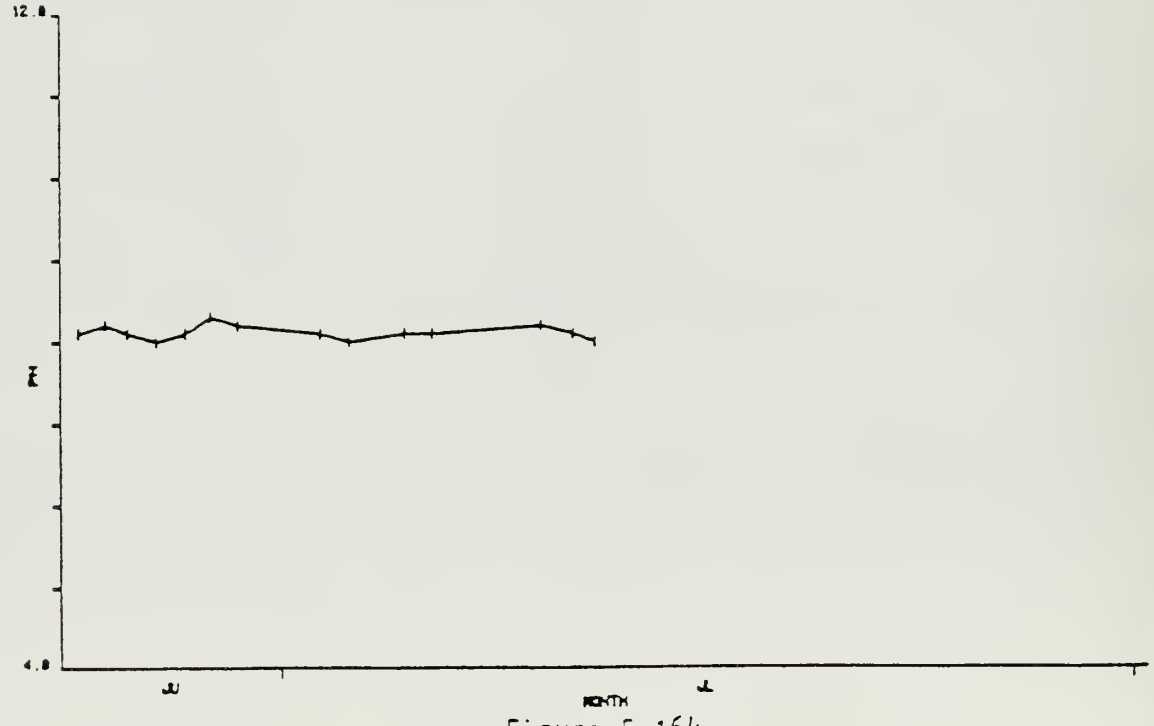

Figure 5-164

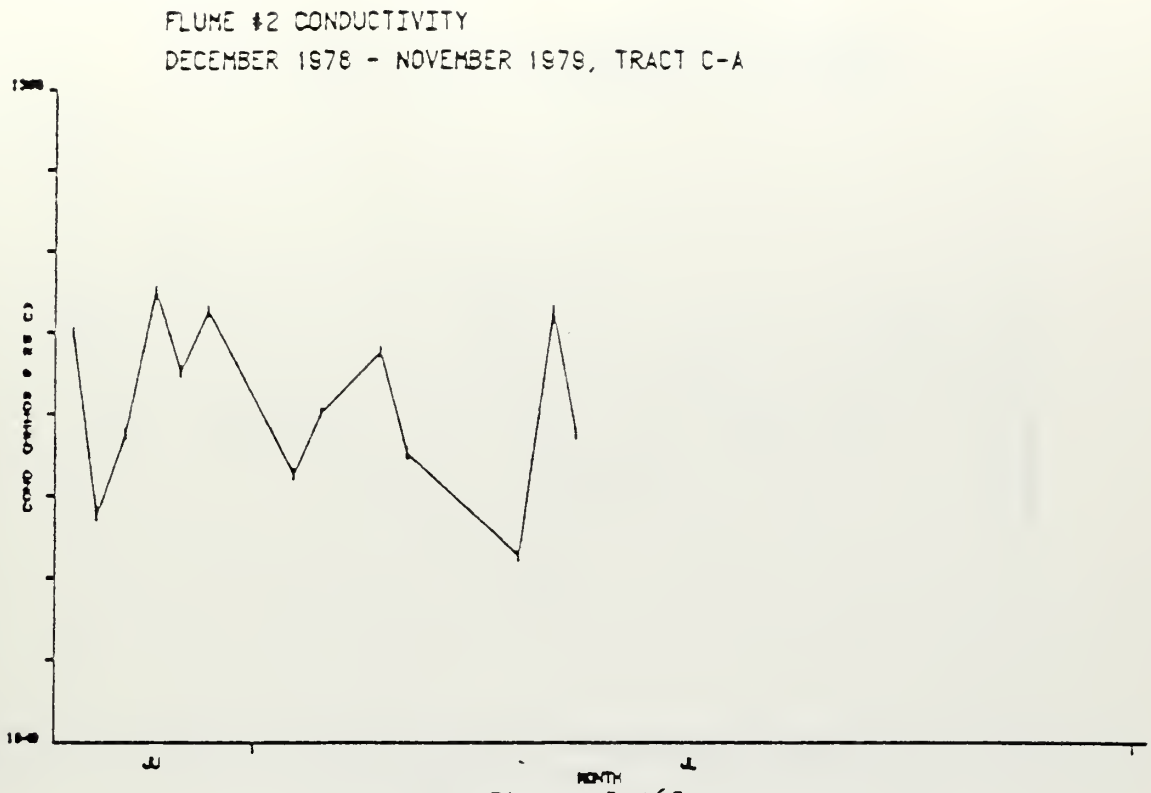

Figure 5-165

FLUME #2 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

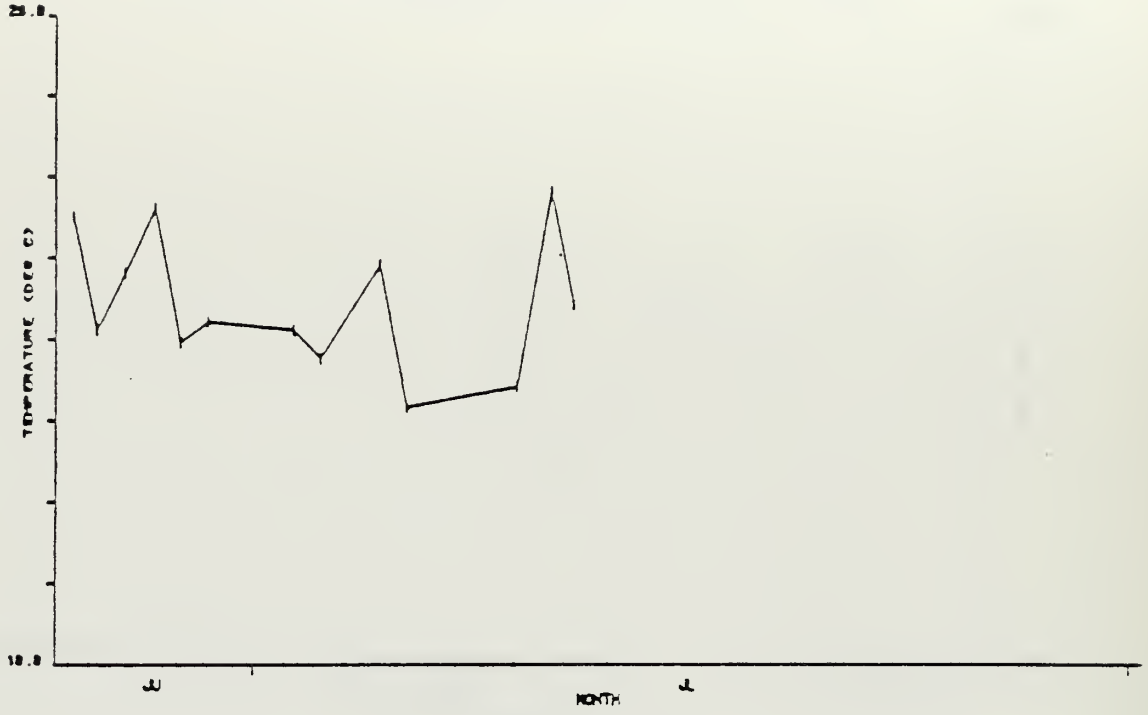

Figure 5-166

FLUME #2 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

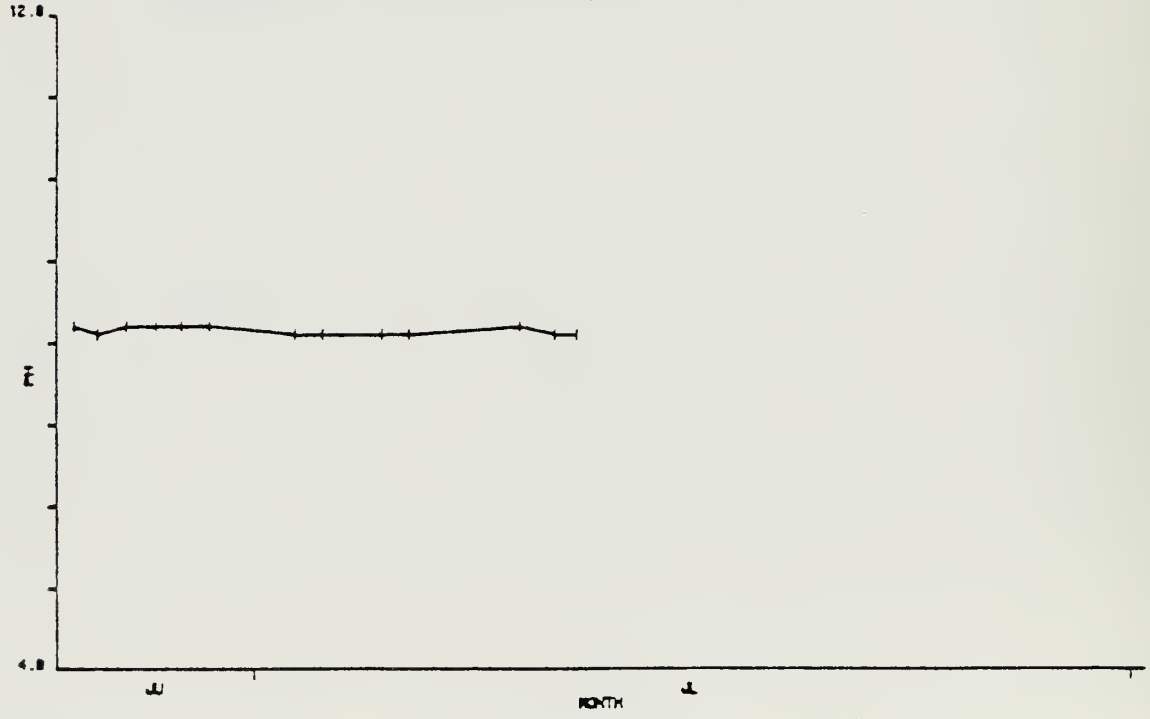

Figure 5-167

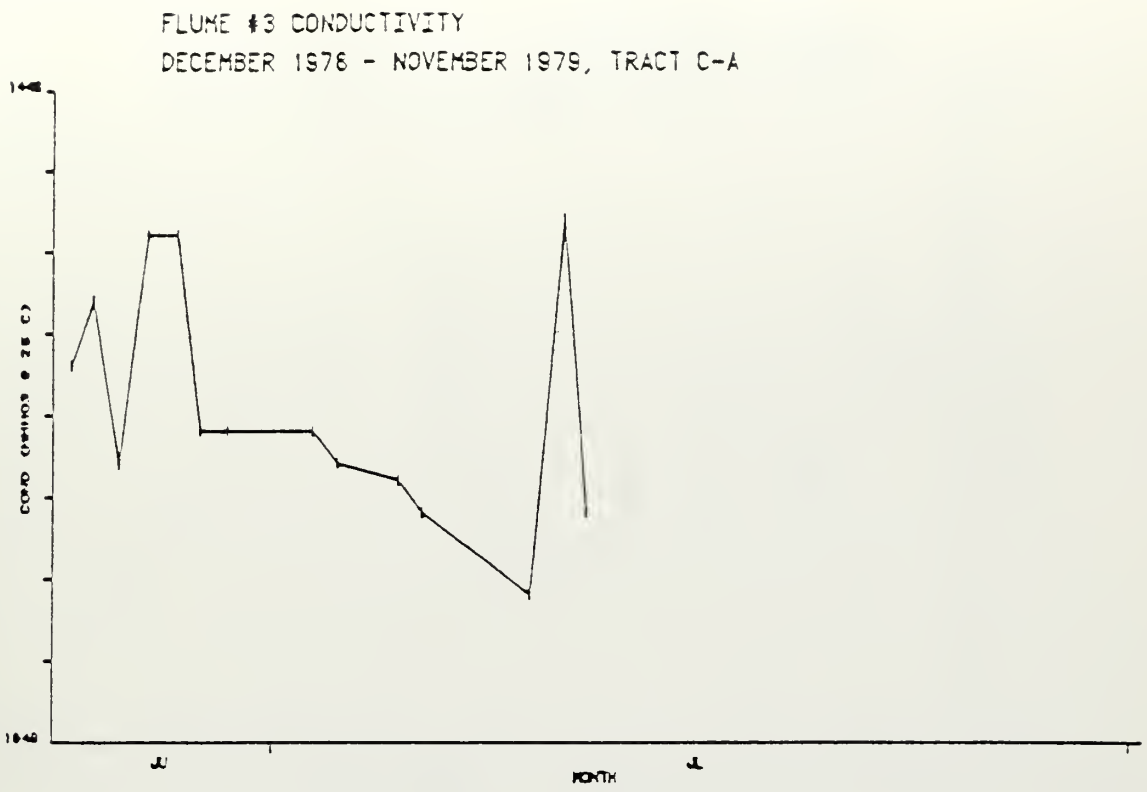

Figure 5-168

FLUME #3 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

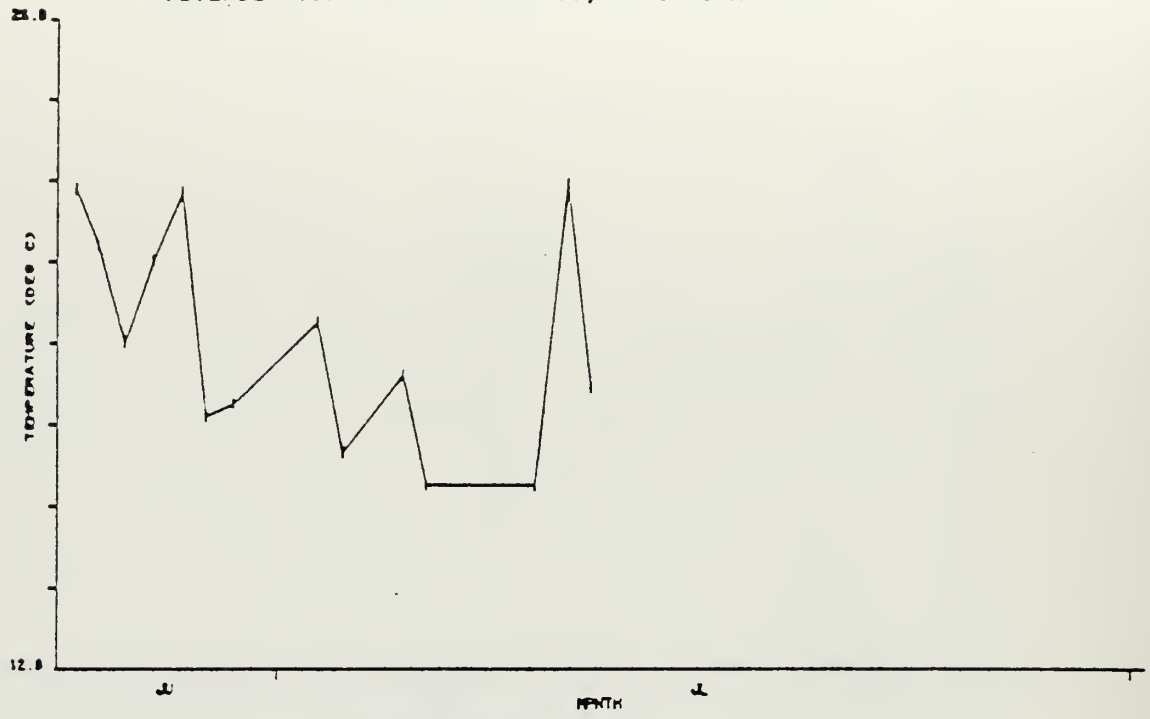

Figure 5-169

FLUME #3 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

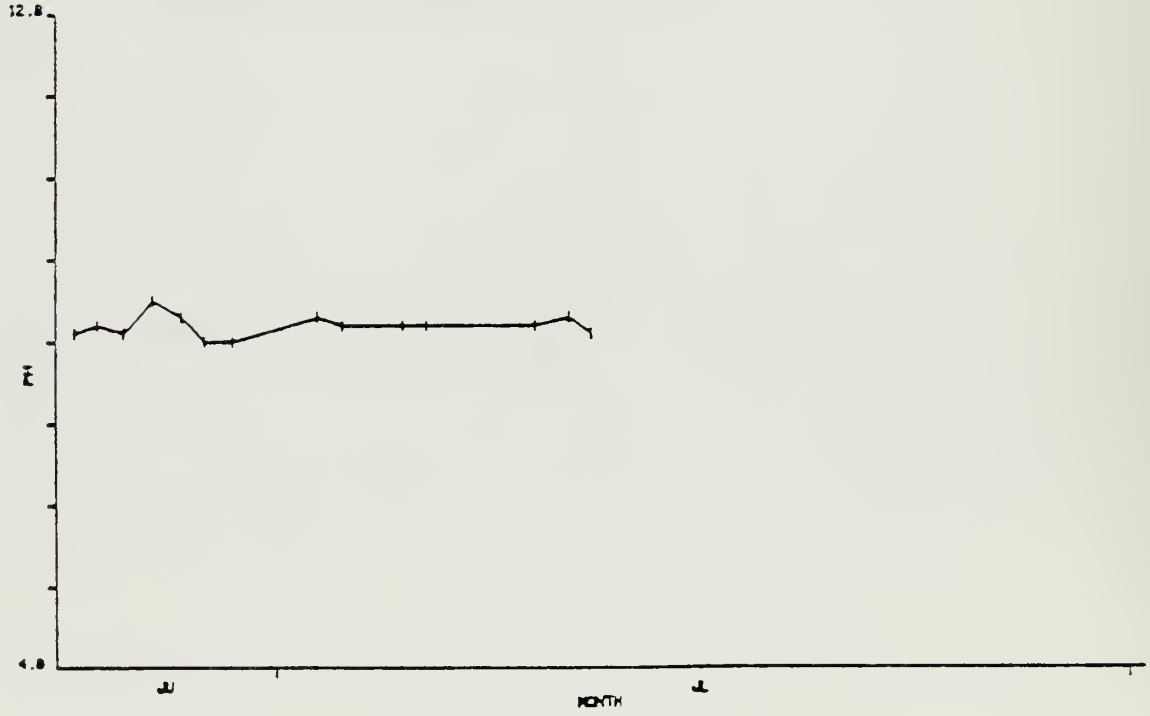

Figure 5-170

FLUME #4 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

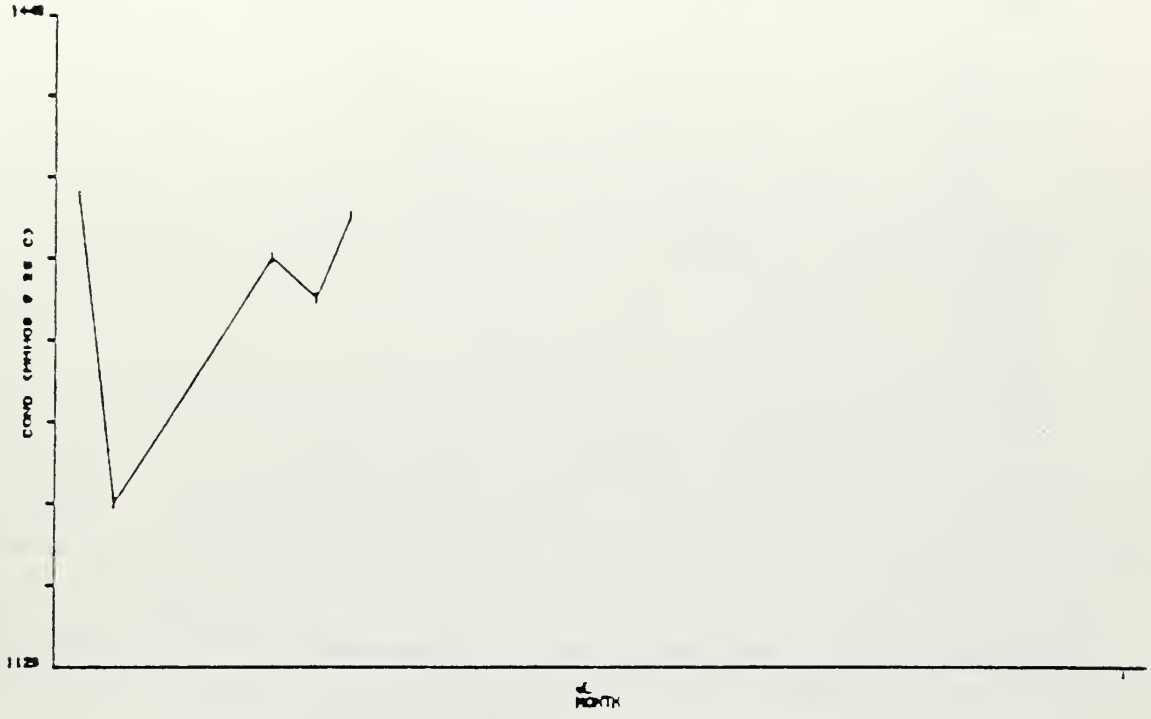

Figure 5-171

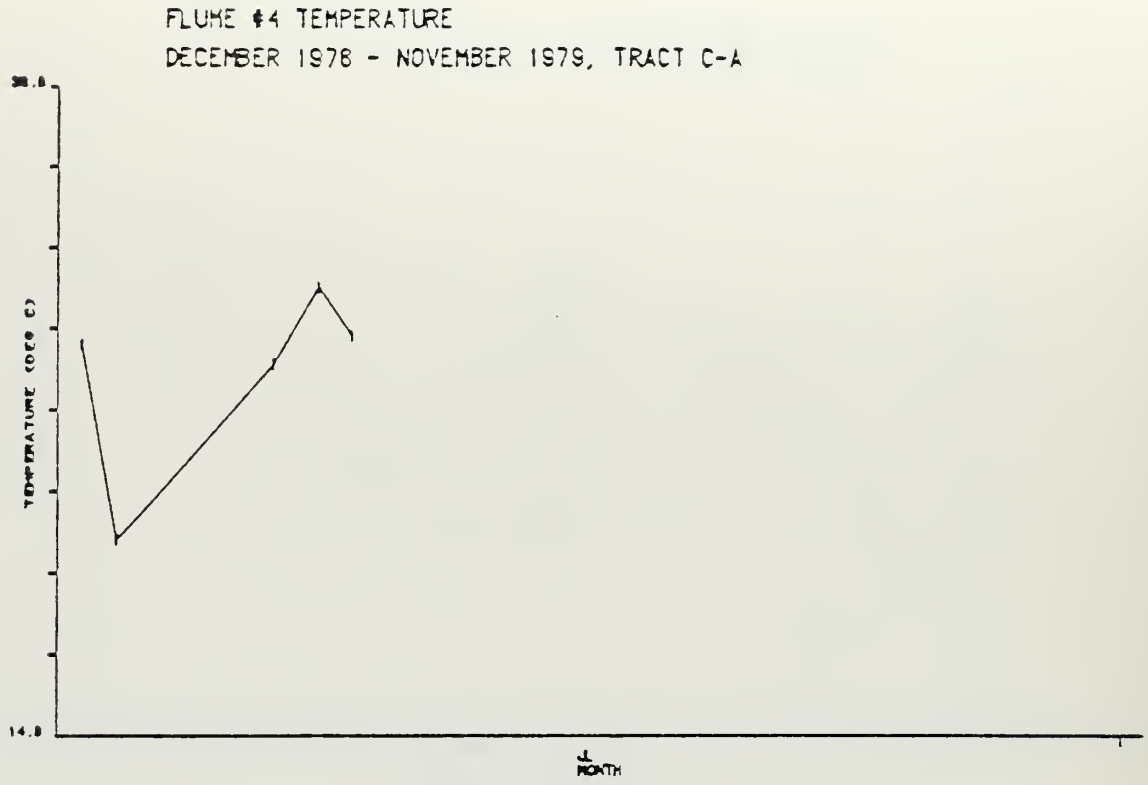

Figure 5-172

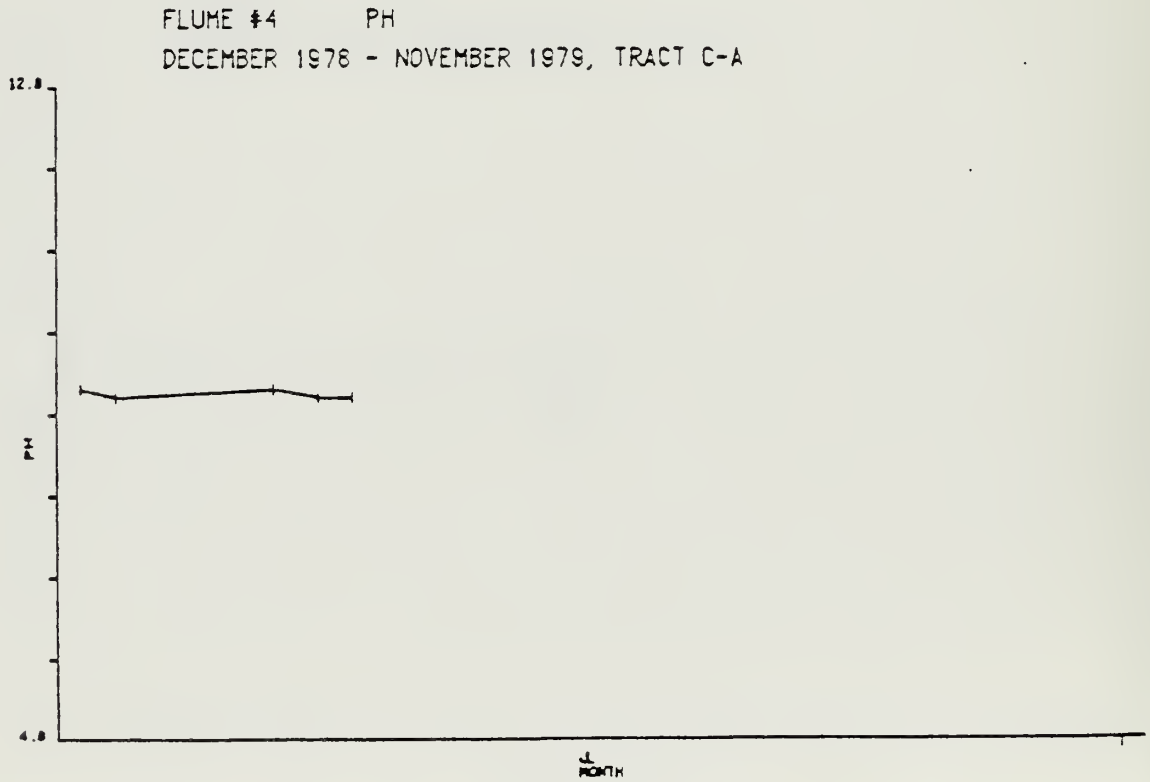

Figure 5-173

Physical data for Flume No. 5 are recorded in Figures 5-174 through 5-176. At this monitoring station, the impacts of both discharged water, and naturally occuring flow are seen. The high conductivity value recorded in early July is consistent with the high conductivity measured in the three flumes upstream. Other conductivity and temperature fluctuations are considered indicative of natural fluctuations caused by runoff from summer storms. There are minor fluctuations in pH, but there is no evidence of a long-term change in water quality.

Six of the 12 alluvial wells drilled in SIR Gulch and water levels in the other six alluvial wells were recorded to determine the effects of the recharge program. The hydrographs for these six wells are shown in Figures 5-177 through 5-182. In Wells No. 1,2,7, and 10, water level measurements do not apparently increase significantly due to the recharge program. A significant, short-term drop in the water level in Well No. 2 during September appears to be a bad data point, as does a short-term increase in water level in Well No. 7 during early August. Wells No. 11 and 12 do not show an increase in water levels, except for one point in mid-September on each hydrograph. Although these two readings could both be the result of measurement errors, they could also be indicative of a short-term rise in water table due to the downgradient movement of a slug of water passing through the alluvium as a result of the recharge program.

Water levels in SIR Gulch Deep Well #1 were monitored to determine whether or not recharge was occurring at depth. The hydrograph for this well is shown in Figure 5-183. Water levels in this well do not indicate a significant change during the months following the recharge program. It can be concluded that if the Surface Induced Recharge program had an impact at depth, it was not dramatic and immediate enough to be detected by the monitoring in this testing program.

Physical paramters which were measured at the point of discharge of dewatering water into the stream are plotted in Figures 5-184 through 5-186. These plots

FLUME #5 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

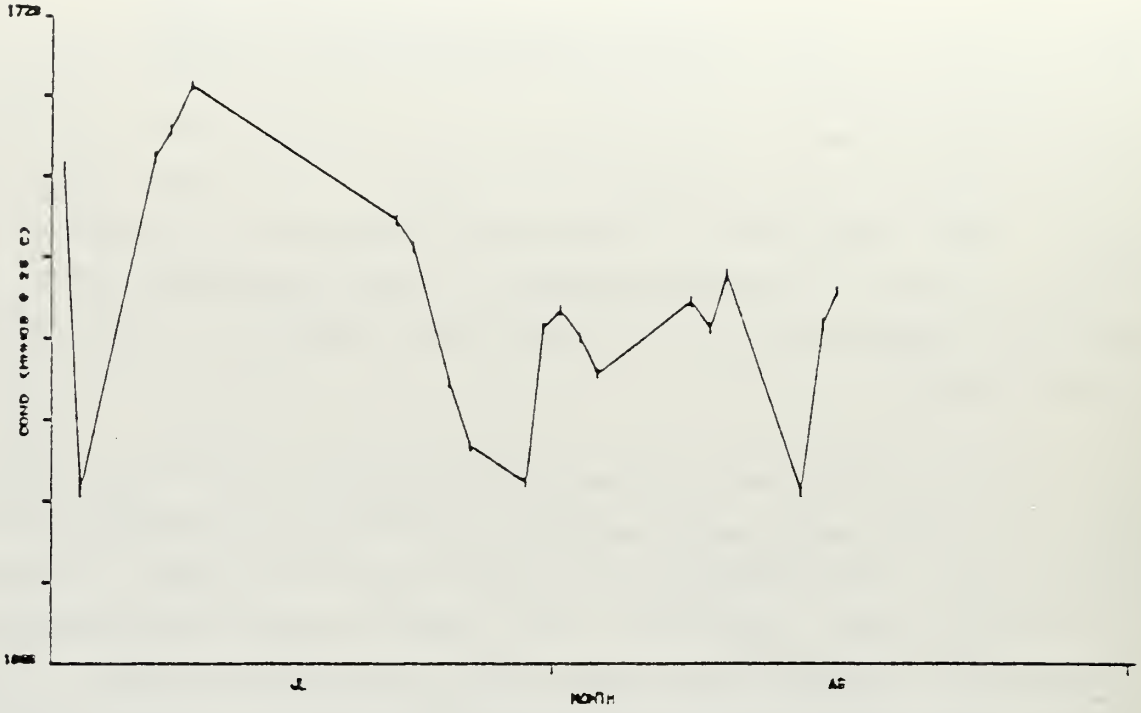

Figure 5-174

FLUME #5 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

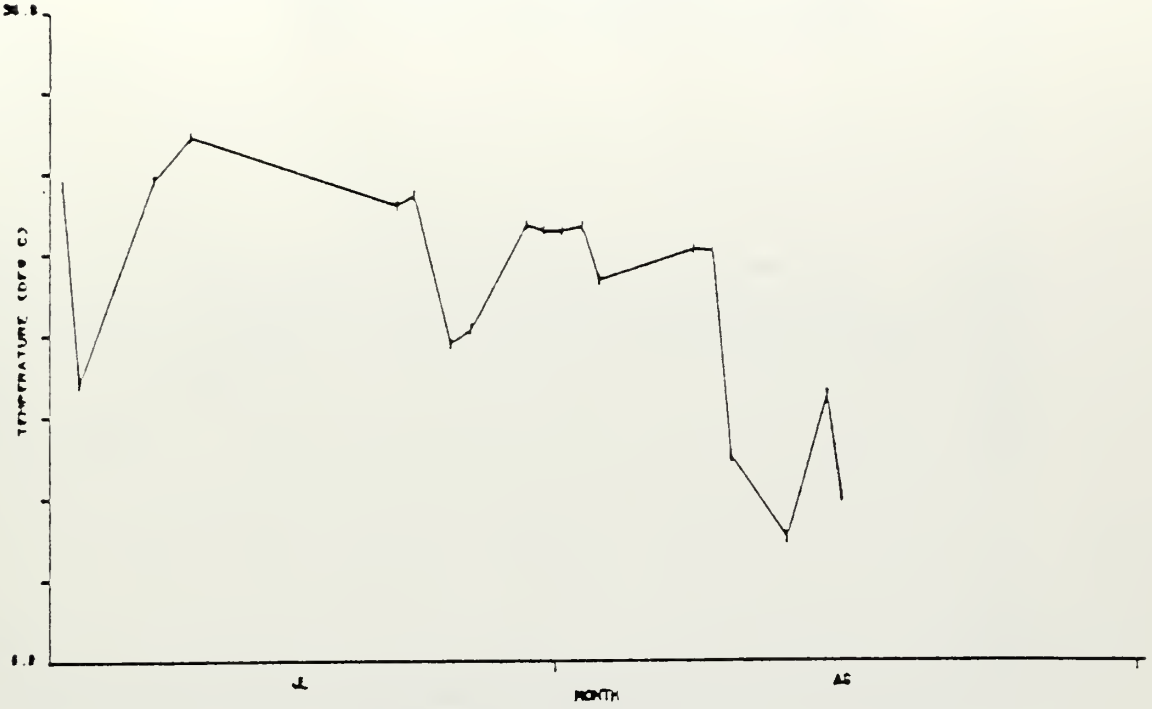

Figure 5-175

FLUME #5 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

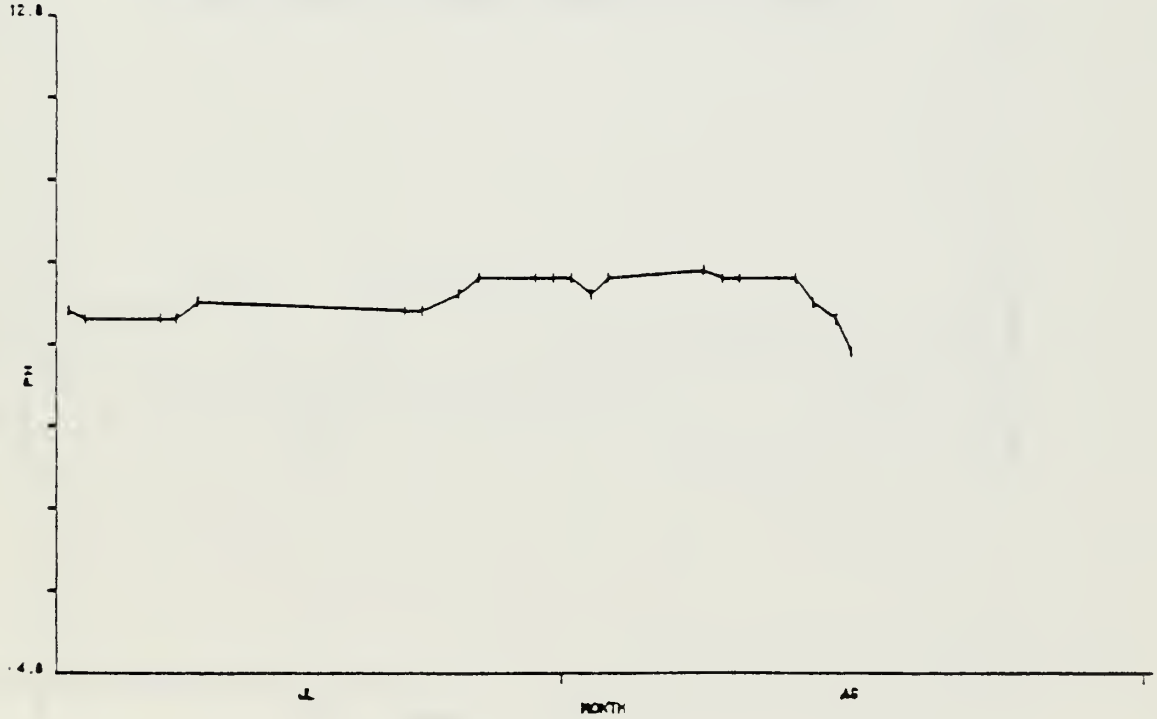

Figure 5-176

SIR GULCH ALLUVIAL WELL #1, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

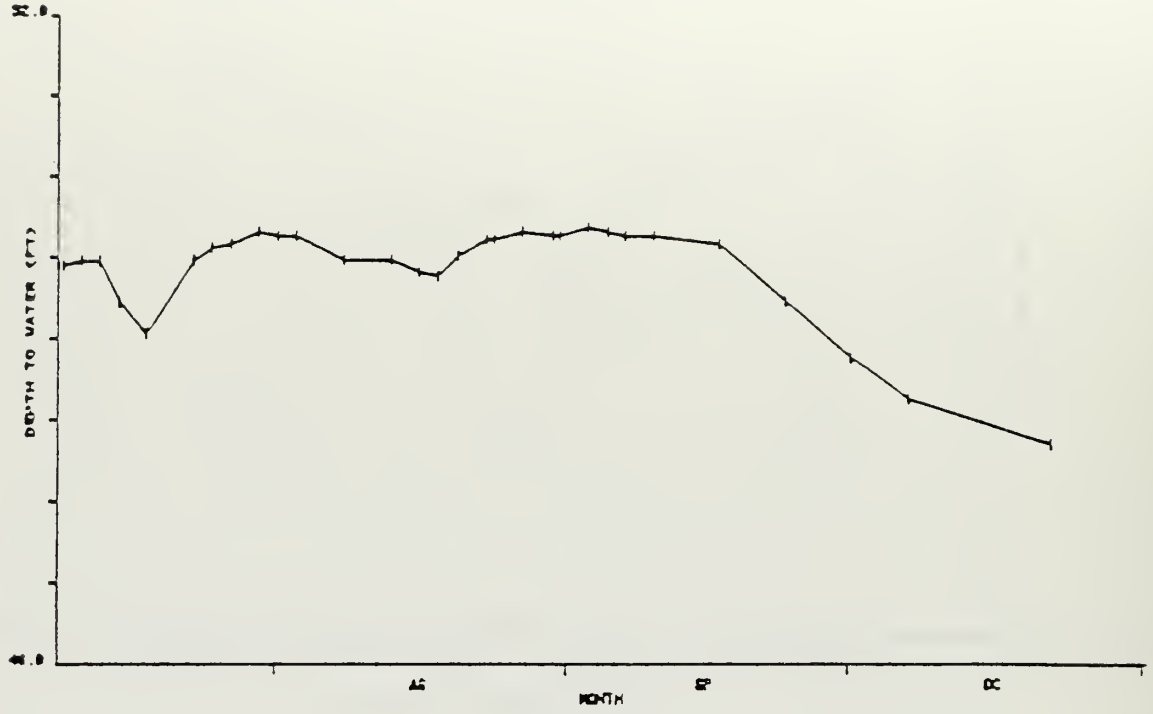

Figure 5-177

SIR GULCH ALLUVIAL WELL #2, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

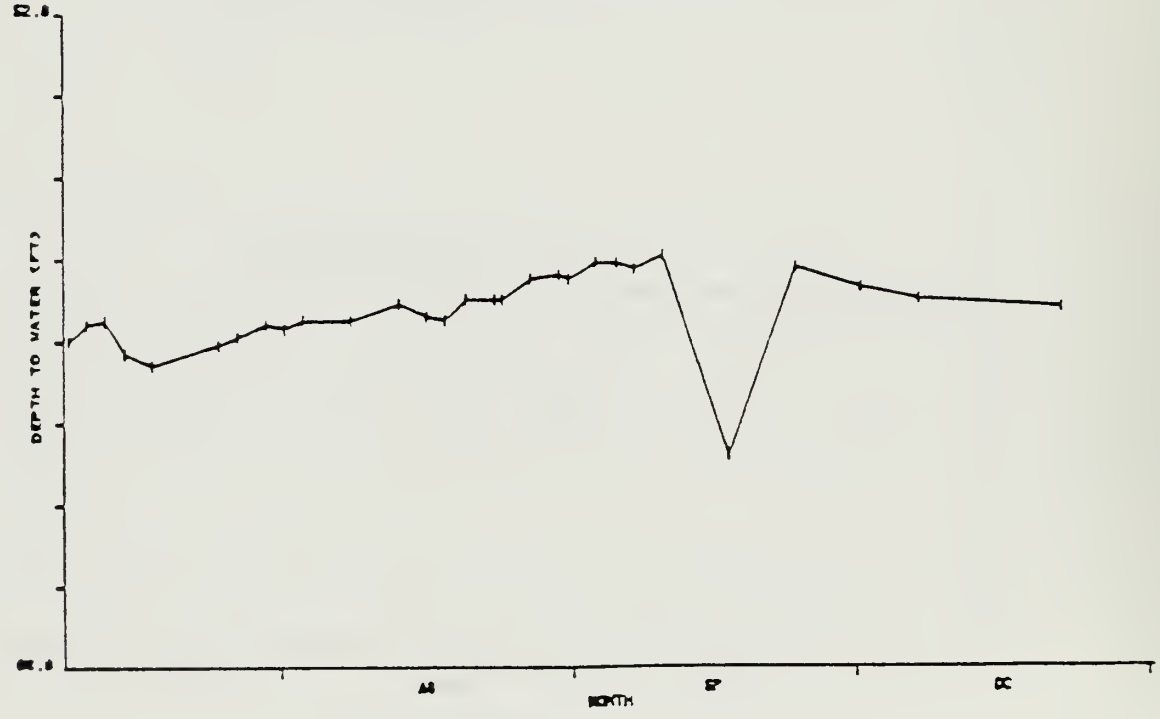

Figure 5-178

SIR GULCH ALLUVIAL WELL #7, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

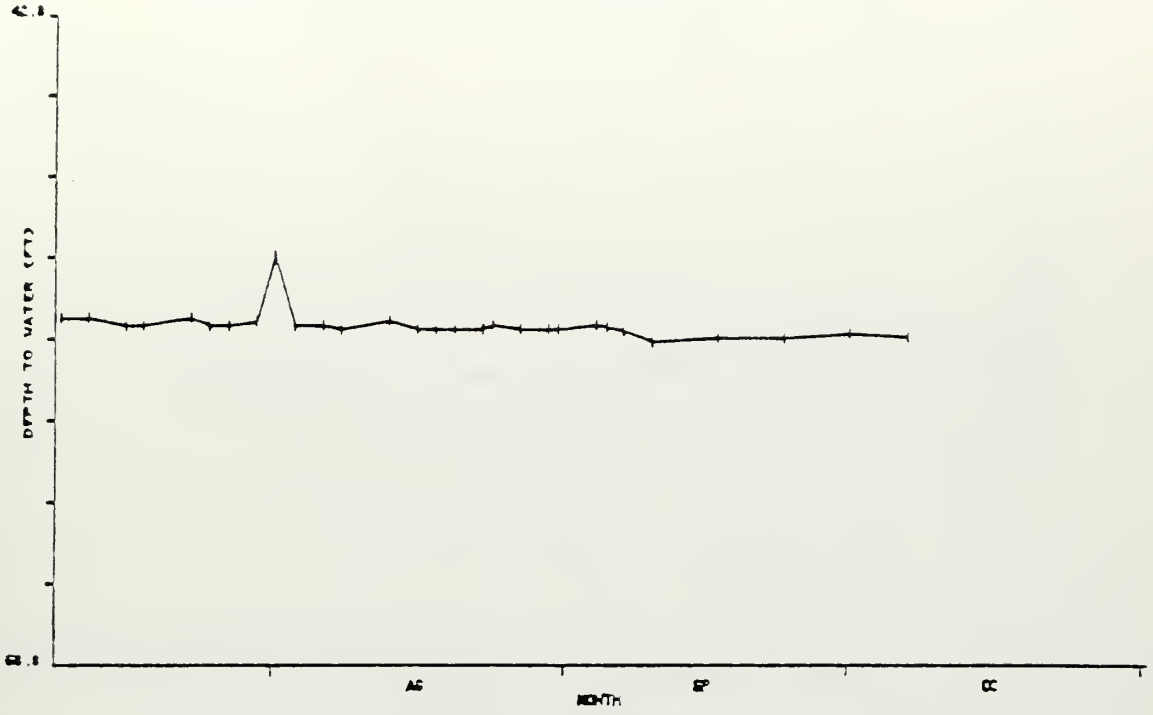

Figure 5-179

SIR GULCH ALLUVIAL WELL #10, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

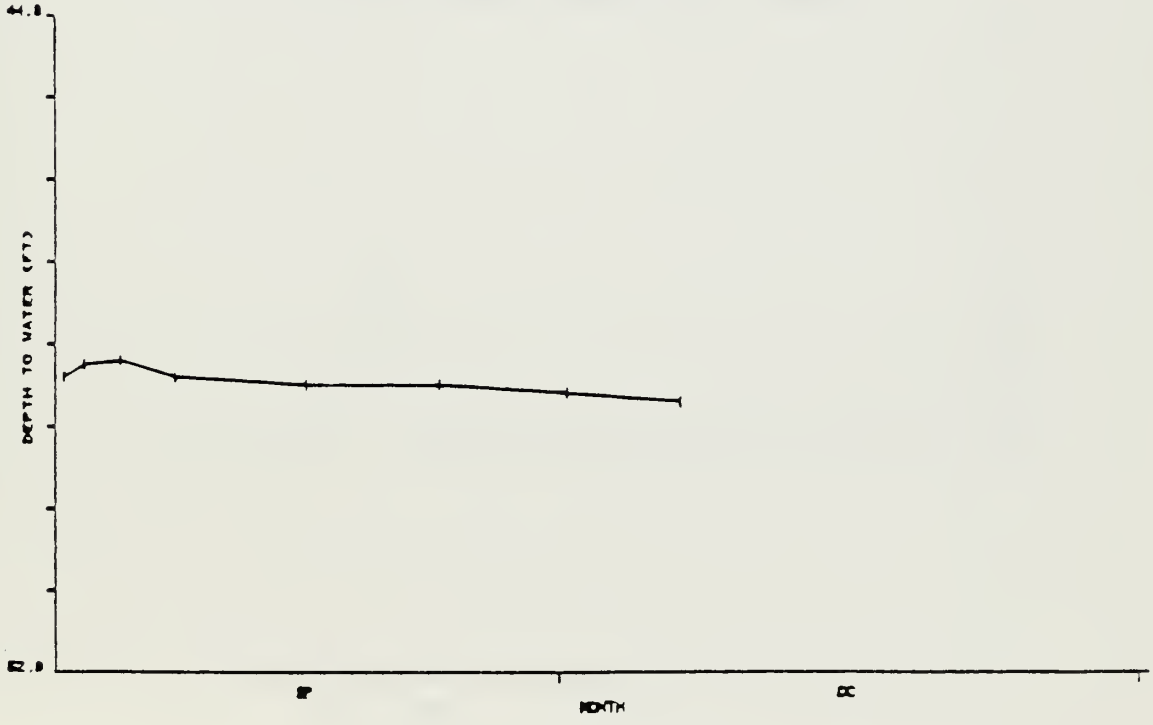

Figure 5-180

SIR GULCH ALLUVIAL WELL #11, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

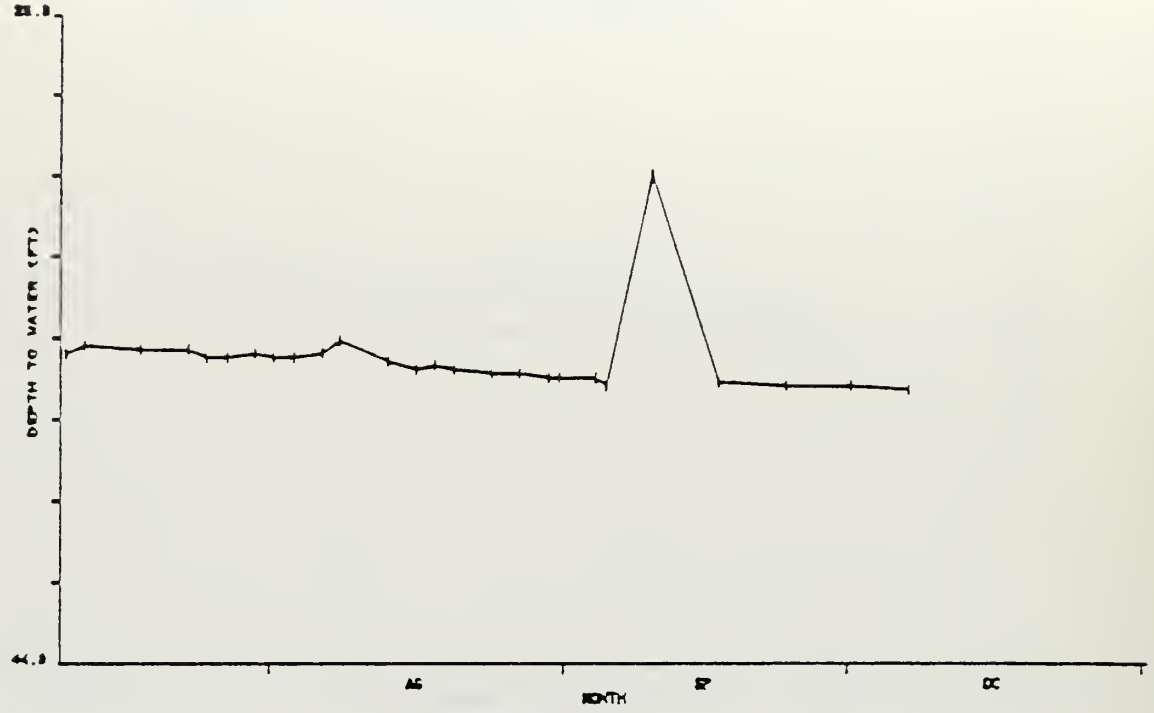

Figure 5-181

SIR GULCH ALLUVIAL WELL #12, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

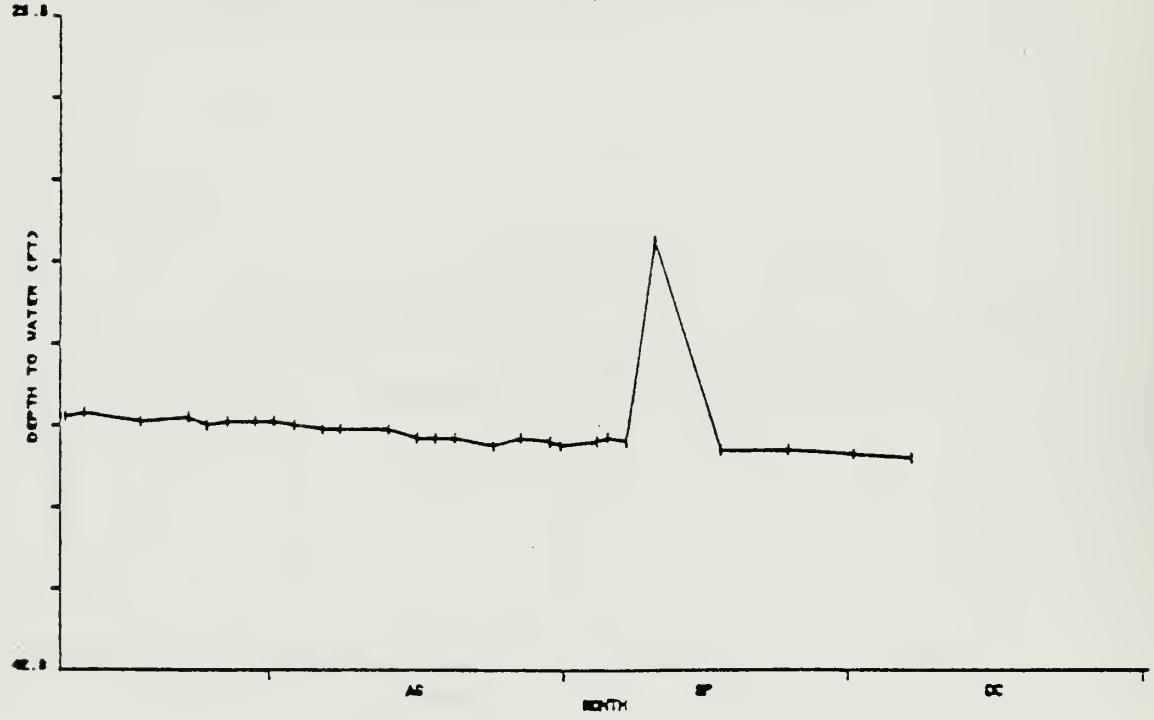

Figure 5-182

SIR GULCH DEEP WELL #1, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

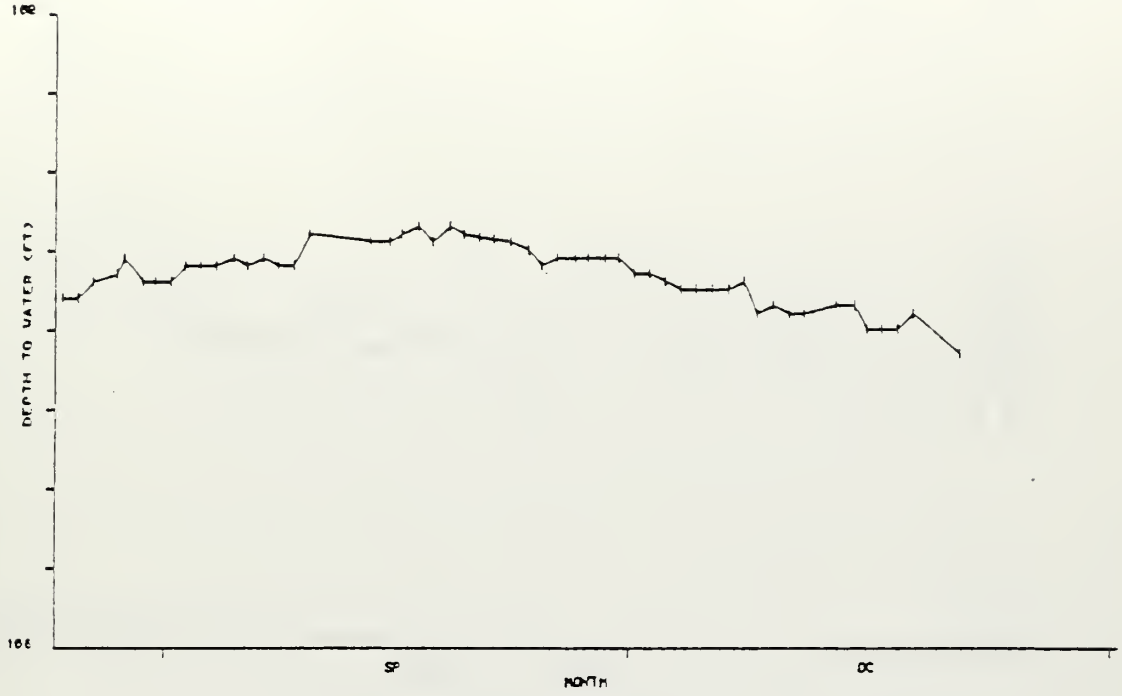

Figure 5-183

SIR GULCH CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

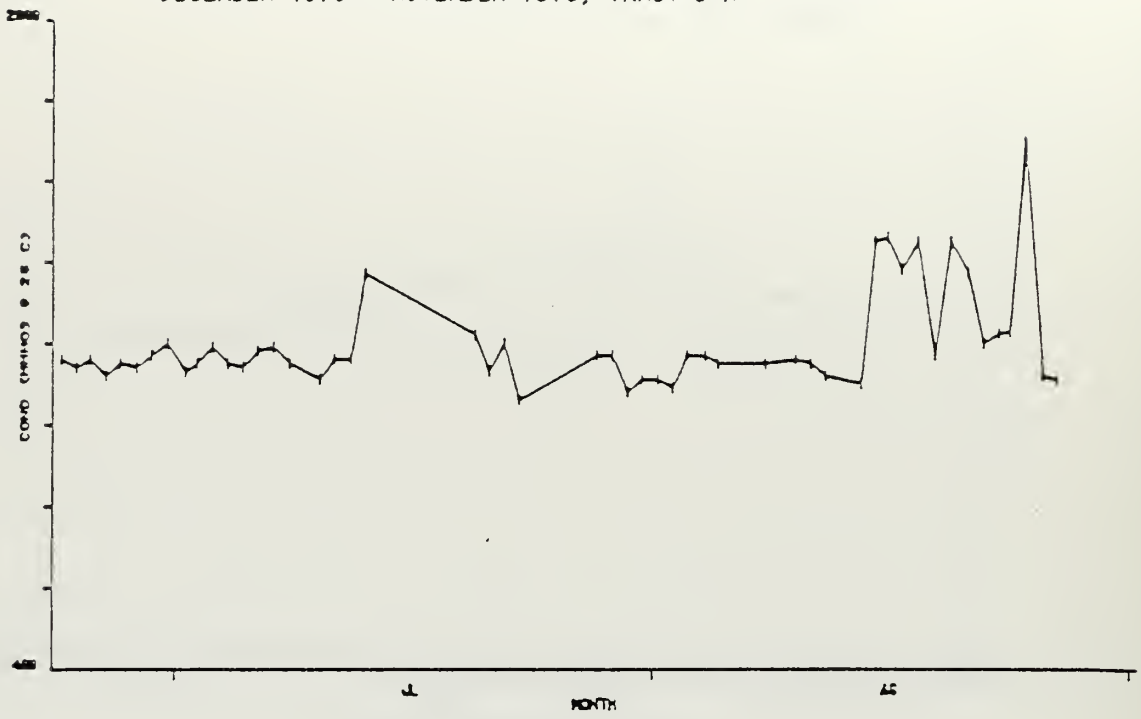

Figure 5-184

SIR GULCH TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

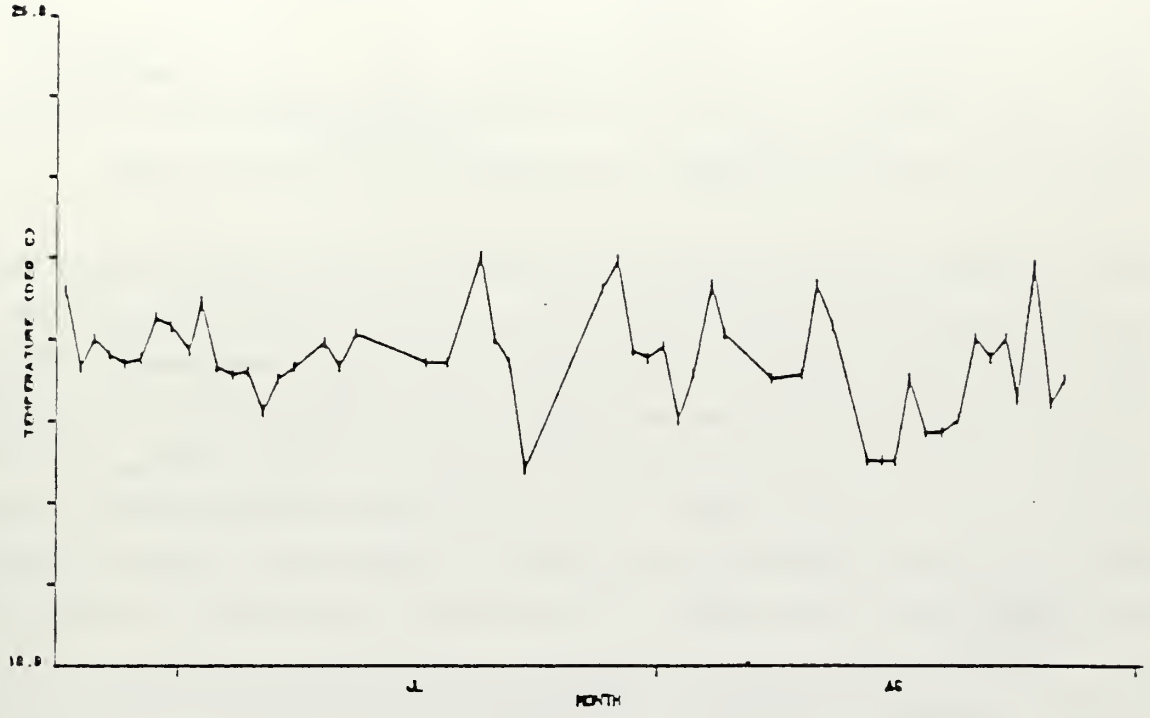

Figure 5-185

SIR GULCH PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

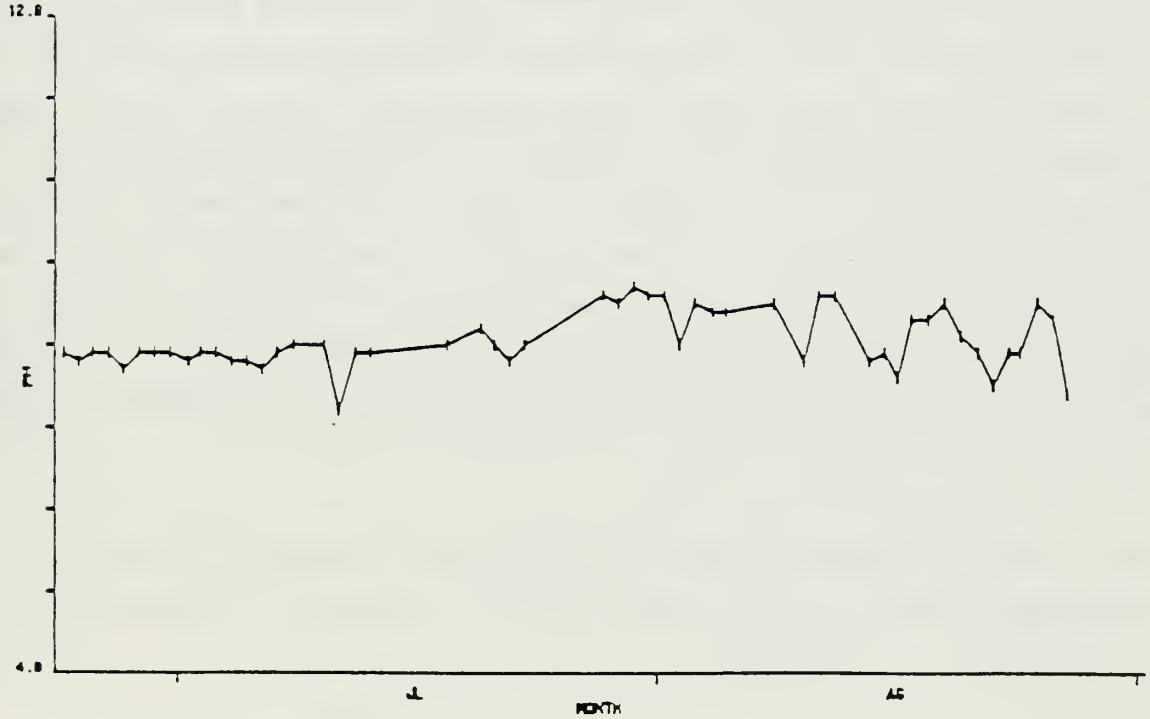

Figure 5-186

indicate the variation in quality and temperature of the dewatering water, before it is exposed to conditions on the surface. The fluctuations of these plots indicate a normal variation in water quality. There are no indications of long-term changes in the quality of dewatering water.

Channel erosion was monitored at five stations during the SIR Gulch testing program to determine whether the excess discharge into the channel produced significant changes in the channel morphology. Measurements for each of the six stations are shown on Figures 5-187 through 5-192. Only minor changes are seen in any of the cross-sections, and most of these changes are attributed to errors in measurement. For such a short-term monitoring program, changes in channel morphology are typically smaller than standard errors of measurement, unless the change in flow regime of the channel is very dramatic.

b. Dewatering/disposal - Mine dewatering was accomplished through the use of three sumps in the mine and a system of five dewatering wells, of which four ceased to produce water during the reporting period. The four wells did not produce because initial dewatering in the mine reduced the operating head to levels below which the wells could produce. The graph (Figure 5-193) shows total water production from the pumping wells and sumps during the reporting period. These flows are monitored as they are discharged into West Retention Pond. Physical data for dewatering well D-5 are plotted in Figures 5-194 through 5-196. The pH shows little variation but temperature decreased and the conductivity increased during the reporting period. Possible explanations for the increase in conductivity are chemical changes due to 1) the depressurization of the aquifer, 2) recycling of reinjection water or, 3) natural variations in different zones of the aquifer. The concurrent temperature decreases indicate that water from higher zones in the aquifer was being produced at the end of the reporting period, supporting interpretation 3.

A map showing drawdown contours for the cone of depression resulting from mine seepage and dewatering for November 1979 is presented in Figure 5-197. The

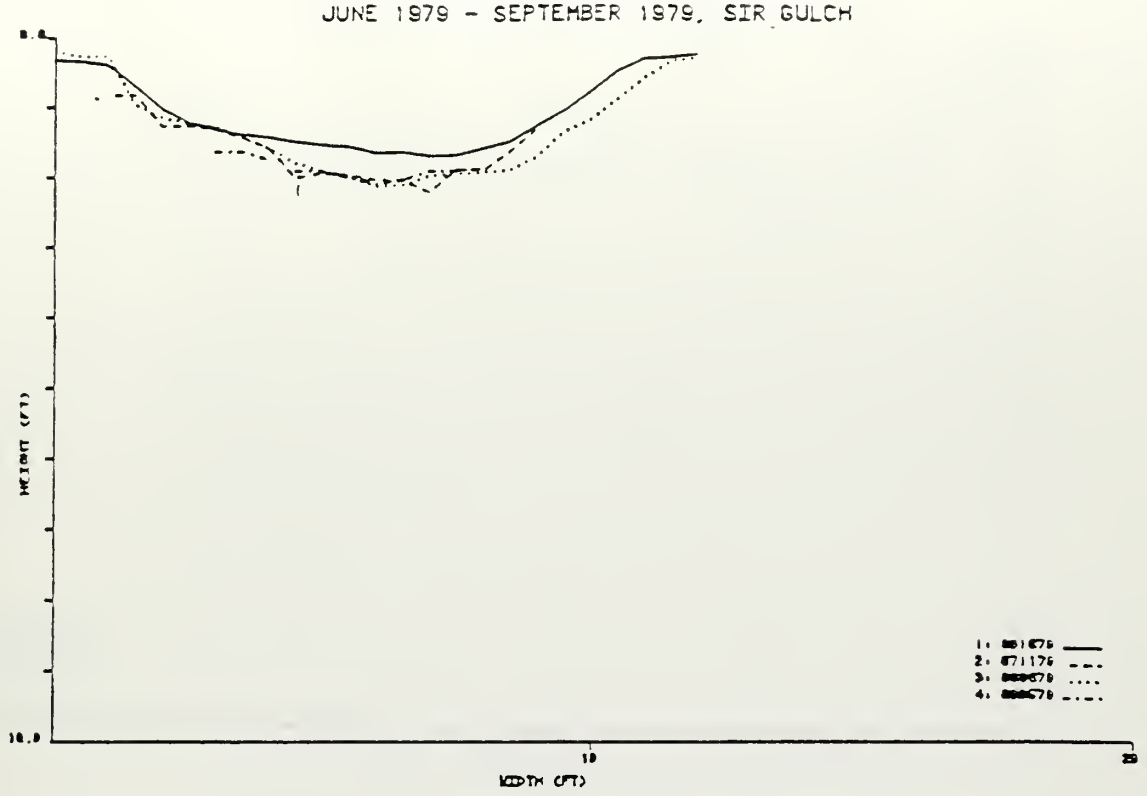

Figure 5-187

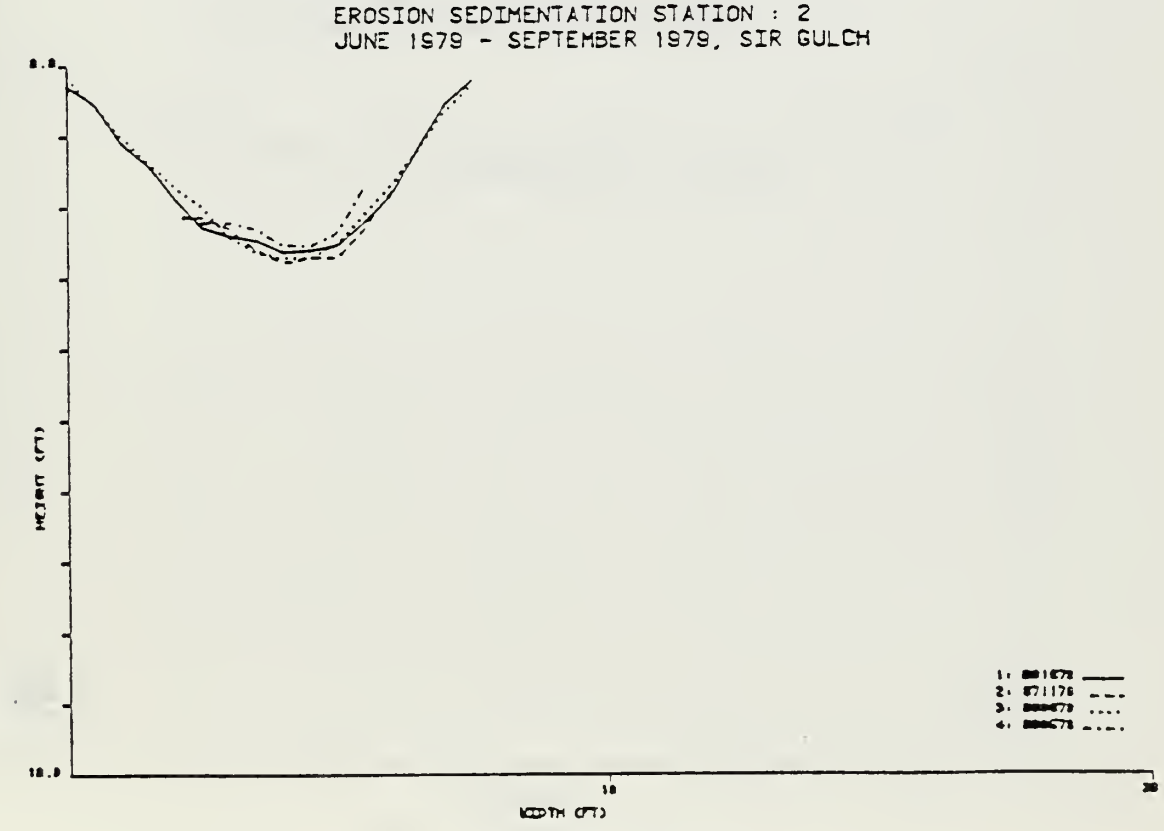

Figure 5-188

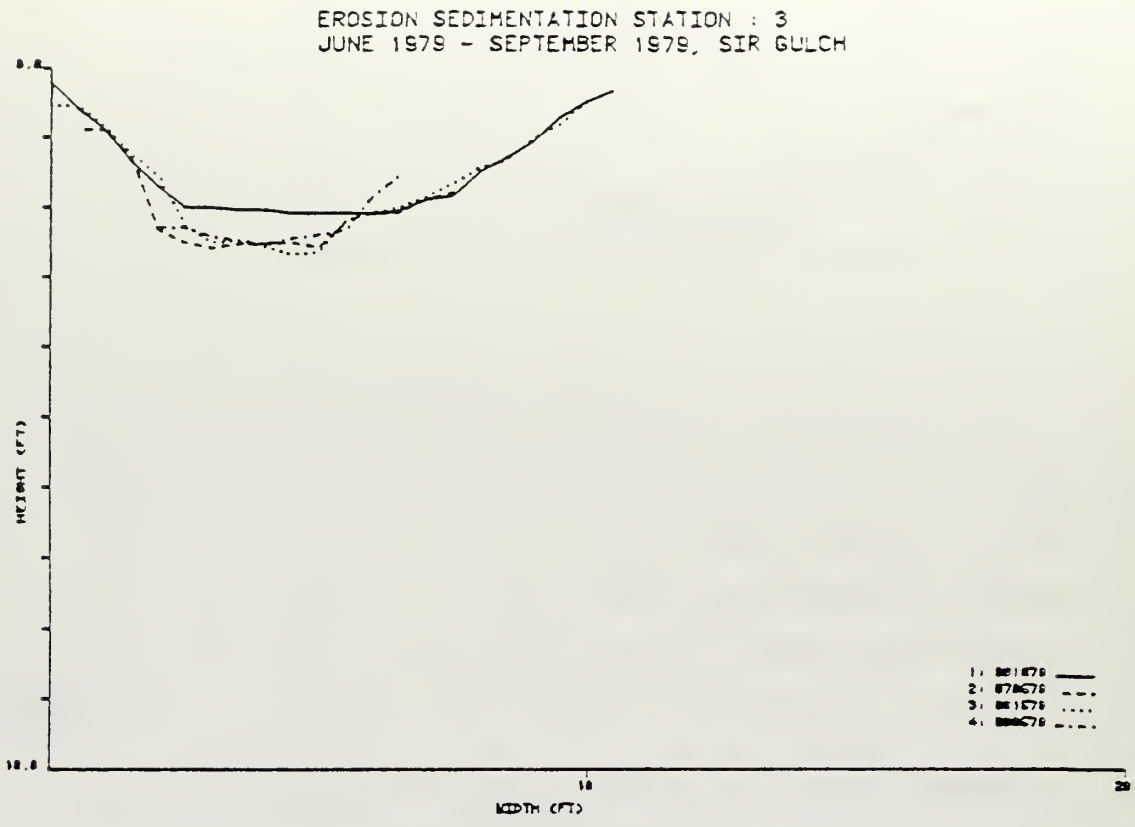

Figure 5-189

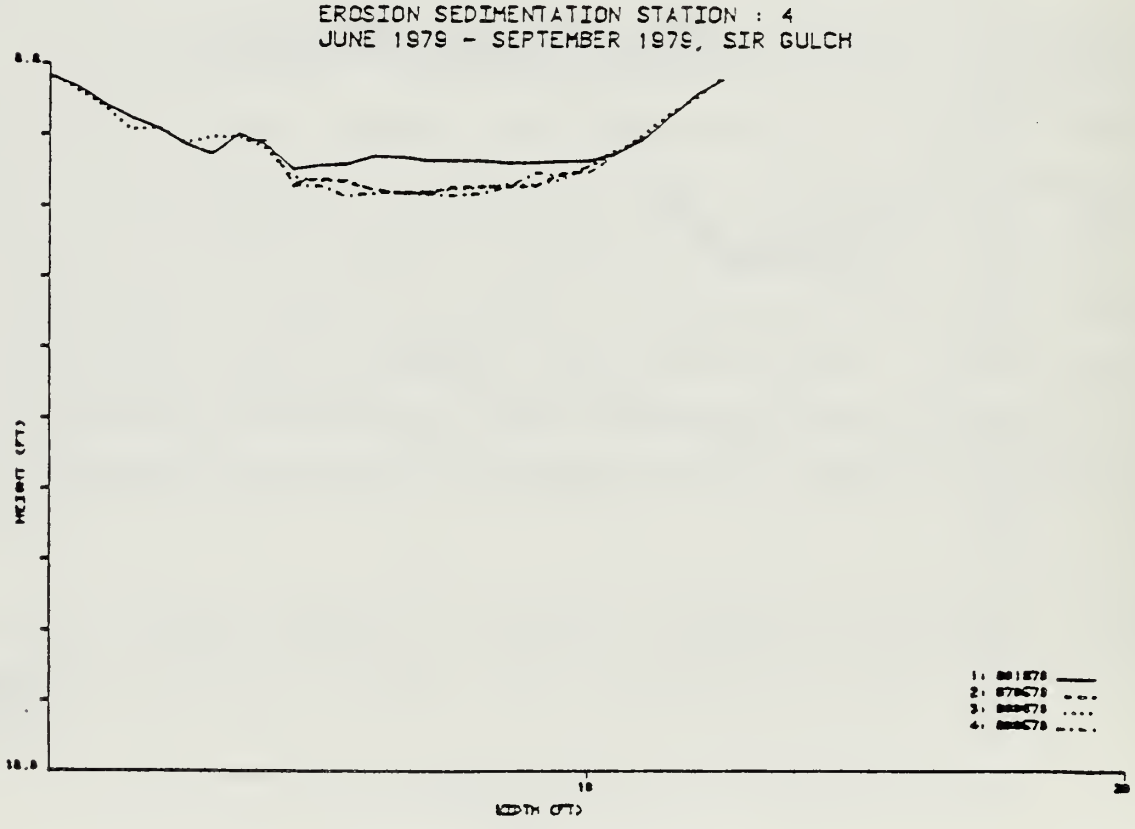

Figure 5-190

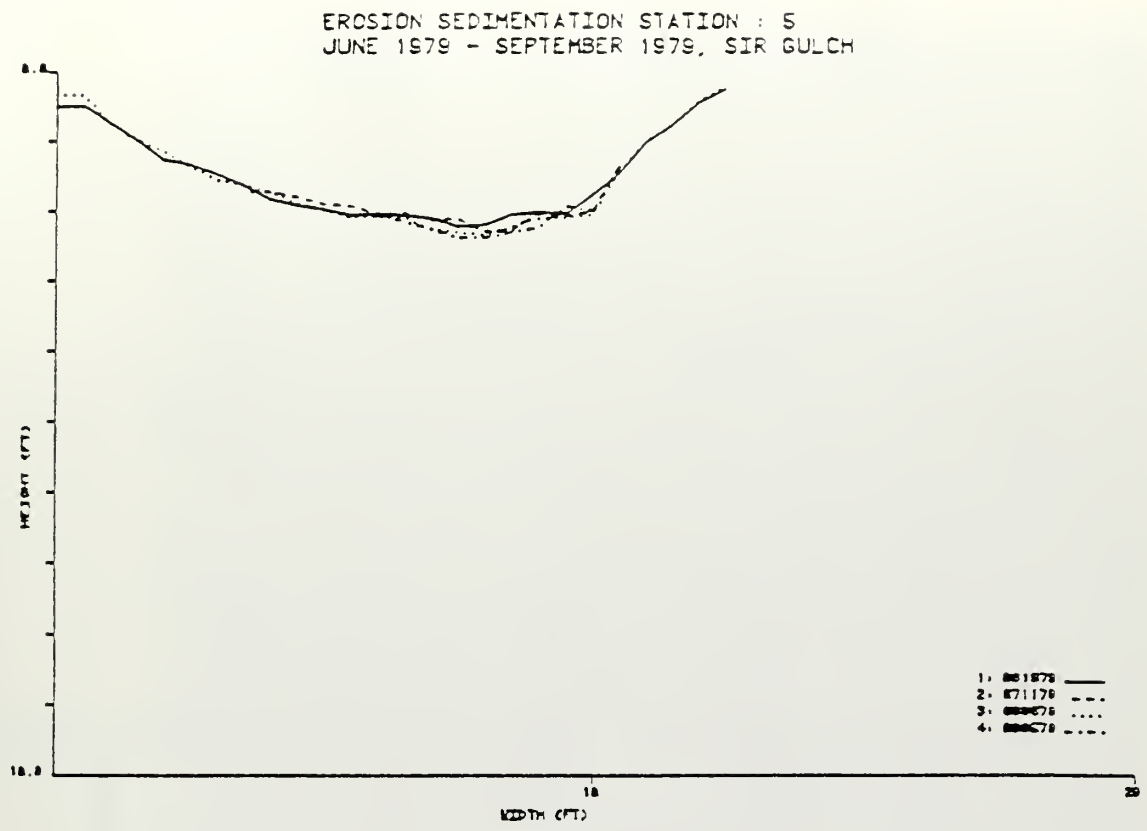

Figure 5-191

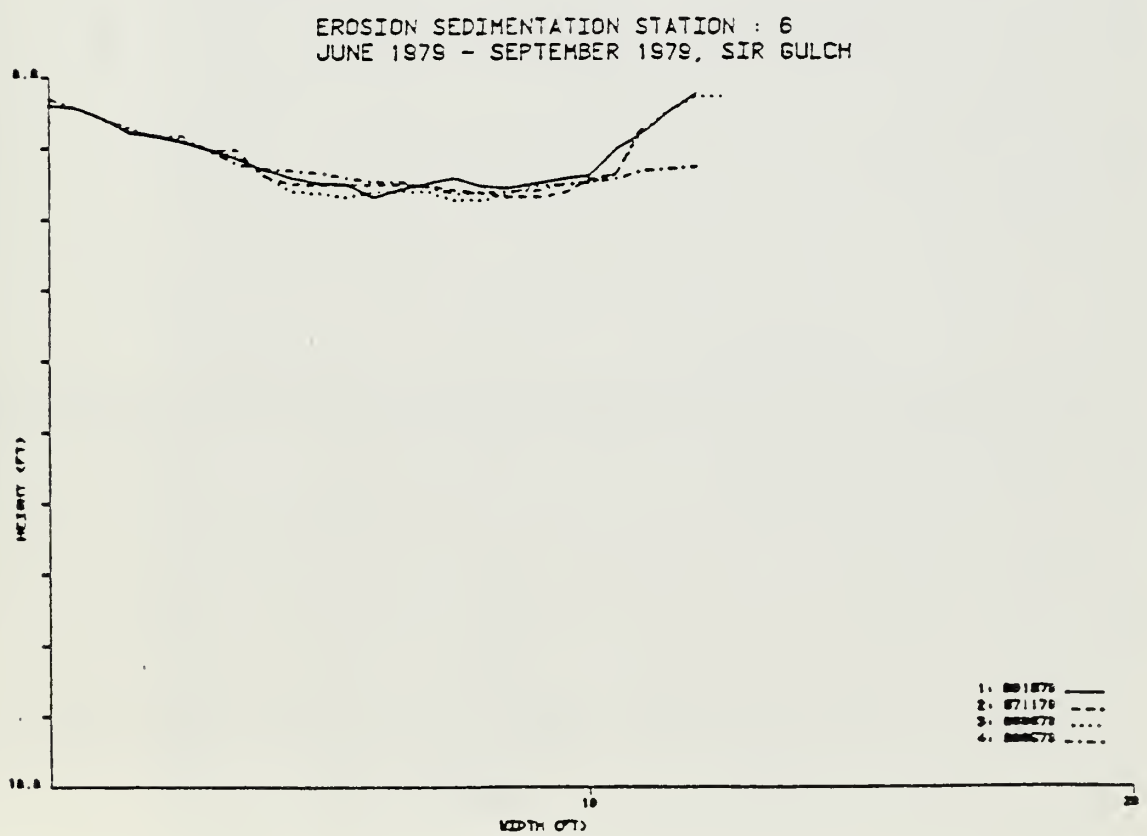

Figure 5-192

D-5 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

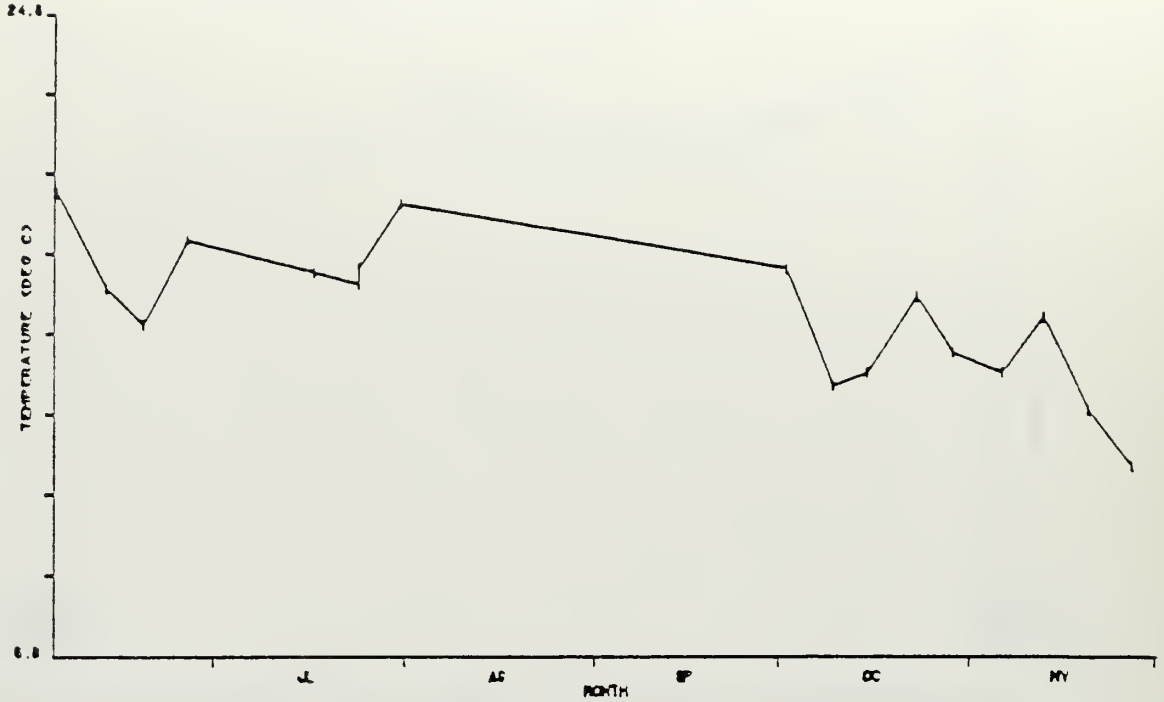

Figure 5-194

D-5 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

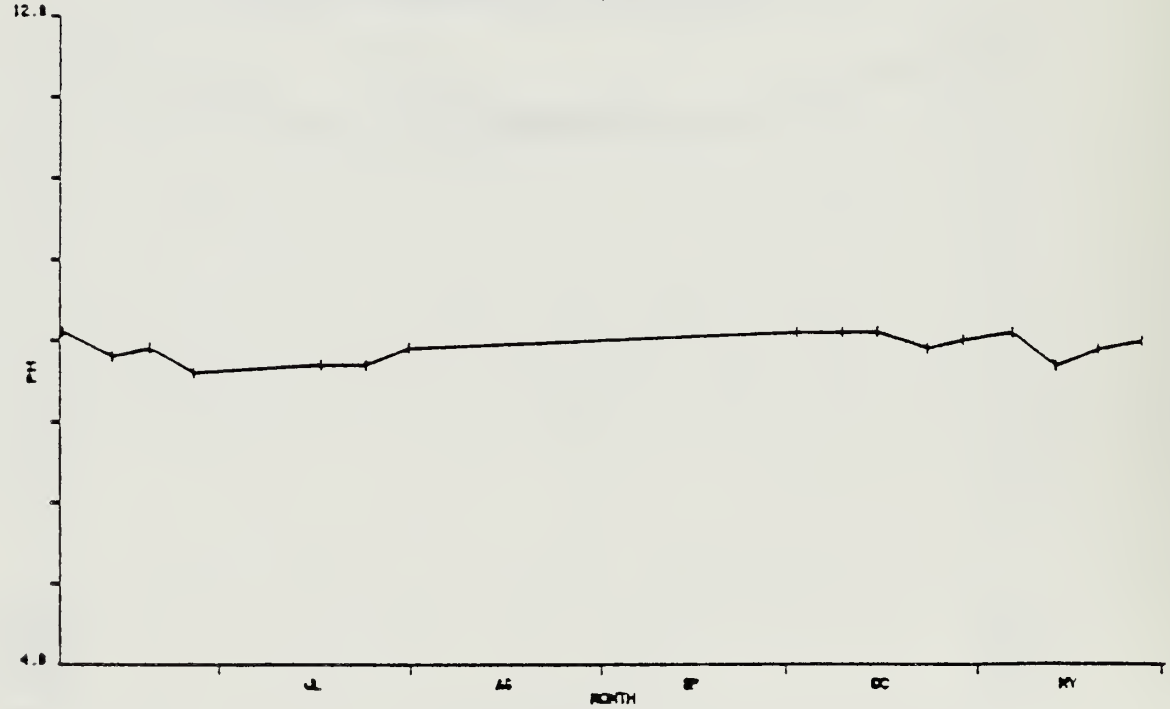

Figure 5-195

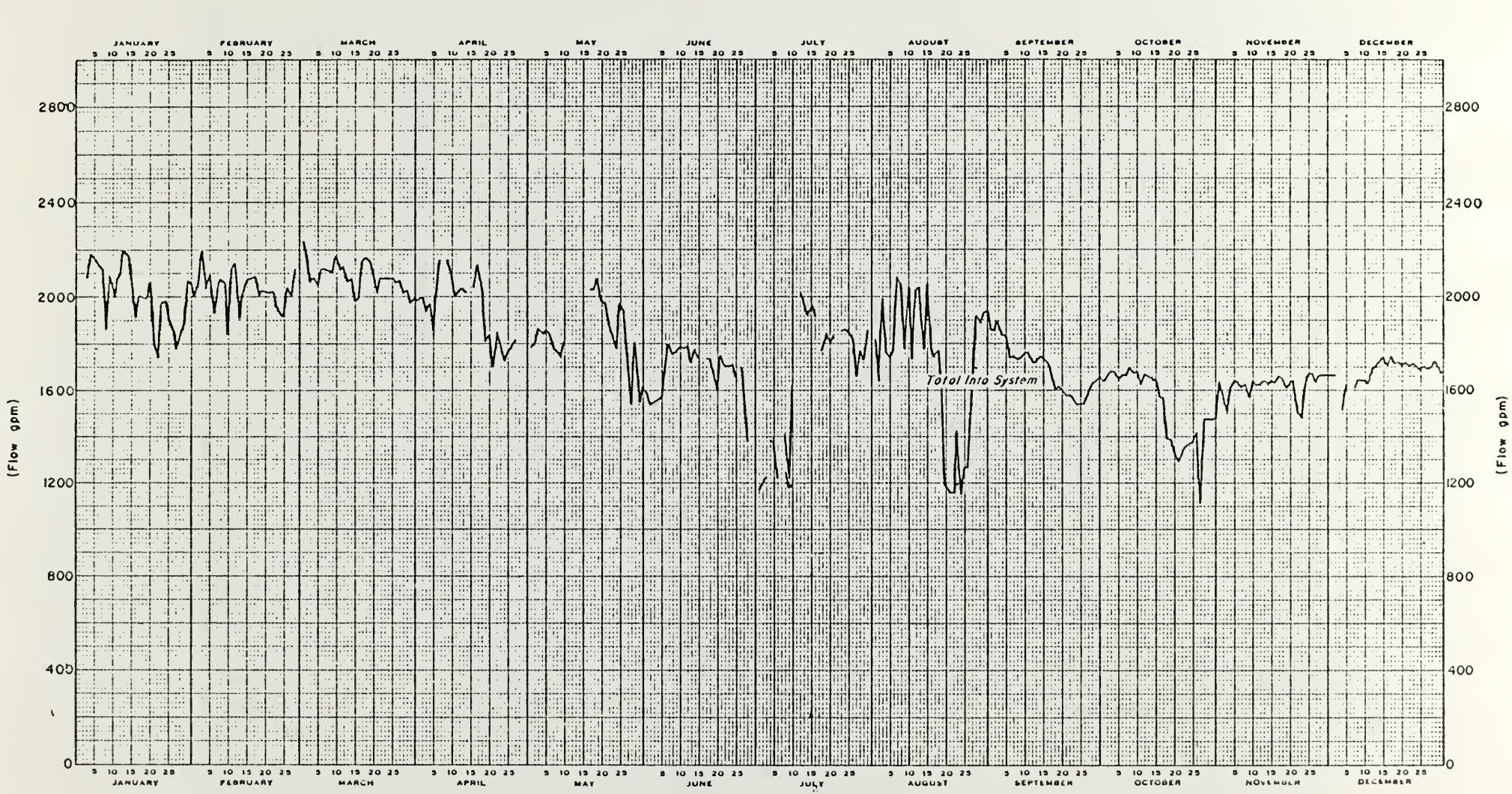
TOTAL WATER PRODUCTION
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
2800
2400
2000
1600
1200
800
400
0
(Flow gpm)
Total Into System

Figure 5-193.

D-5 CONDUCTIVITY

DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

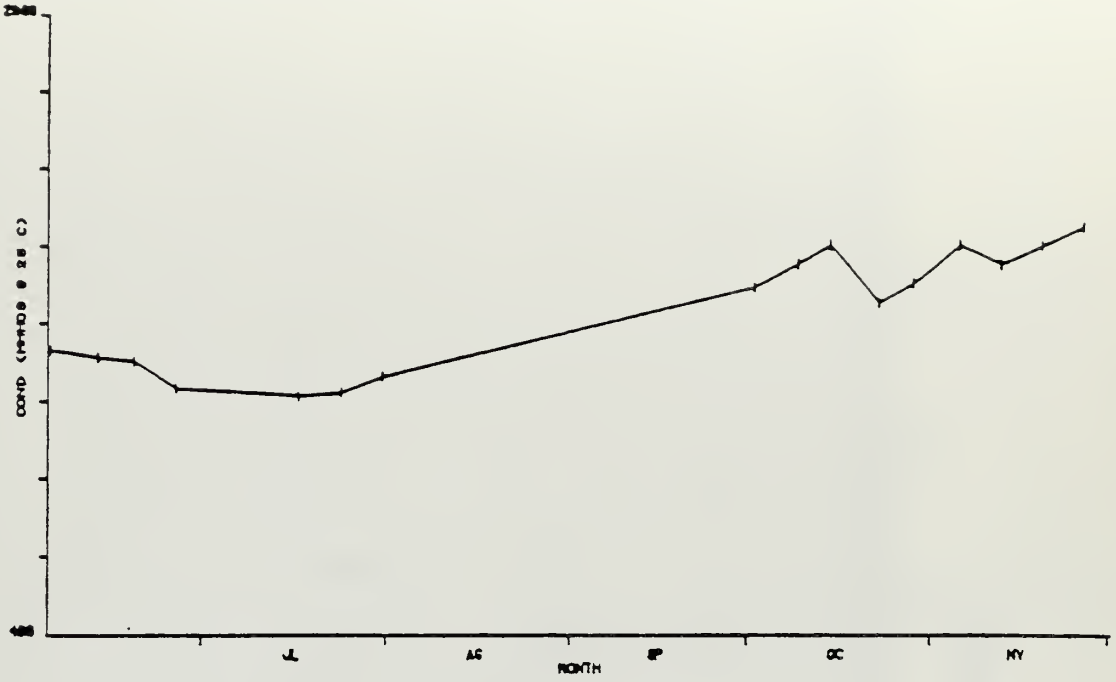

Figure 5-196

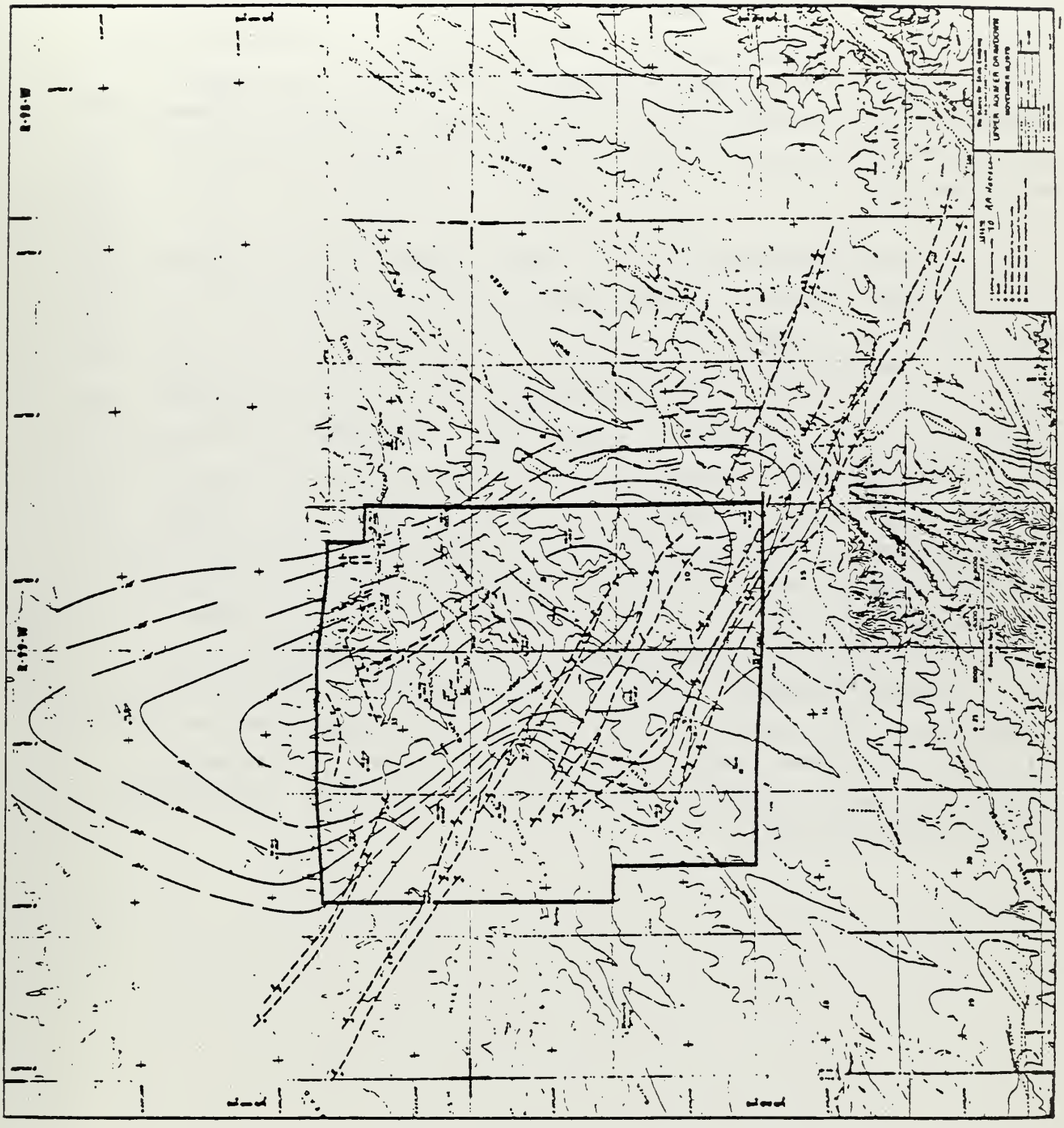

Figure 5-197

greatest extension of the drawdown cone is occuring to the southeast and to the north of the shaft. Northwest-southeast trending faults south and west of the shaft are apparently acting as hydraulic barriers to the spread of the cone of depression to the south, southwest, and west. The failure of the cone of depression to extend to the northeast appears to be due to intrinsic aquifer anisotropy coupled with extensive reinjection in the northeast corner of the Tract.

A plot of total water disposal for the reporting period is shown on Figure 5-198. Total water disposal is the outflow from the West Retention Pond. Dewatering and mine seepage water discharged into West Retention Pond is held there until the operational scheme calls for its disposal either as reinjection, consumptive use, or surface discharge. Graphs for each of these components are shown in Figures 5-199 through 5-201. Consumptive use (Figure 5-199) is the water that is withdrawn from West Retention Pond and placed in a storage tank to be used as needed for fire water, drilling water, or other construction uses. The graph in Figure 5-199 indicates the rate of withdrawal from West Retention Pond to refill the tank. Surface discharge (Figure 5-200) has been decreasing, particularly since September. There are two reason for this: 1) the quantity of water withdrawn from the mine as seepage and dewatering water had decreased slightly, and 2) in September, reinjection was resumed and surface discharge curtailed. Reinjection (Figure 5-201) was reinstated in September, and has almost doubled since then. The summary of production of water from the mine, reinjection, and discharge, and consumptive use is shown on Table 5-25.

Table 5-25. Summary of Water Production

Month	Prod. MG	Reinj. MG	Disch. MG	(-) Losses (+) Accumula.	Cons. MG
Jan	89.0	55.3	38.6	-4.9	0
Feb	80.4	37.7	45.3	-2.6	0
Mar	92.0	----	92.0	0	
Apr	83.0	----	81	0	2.0
May	82.1	----	78.9	+2.9	.3
Jun		----			
July		----			
Aug	220.9*	----	15.9/71.4*	-14.1*	4.0*
Sep					
Oct					
Nov	212.6 *	97.5*	93.8 *	+12.1*	9.2*
Dec	75.2	67.4	.1	+4.5	3.2
	935.2	257.9	660.7	-2.1	18.7

* = Three month accumulations

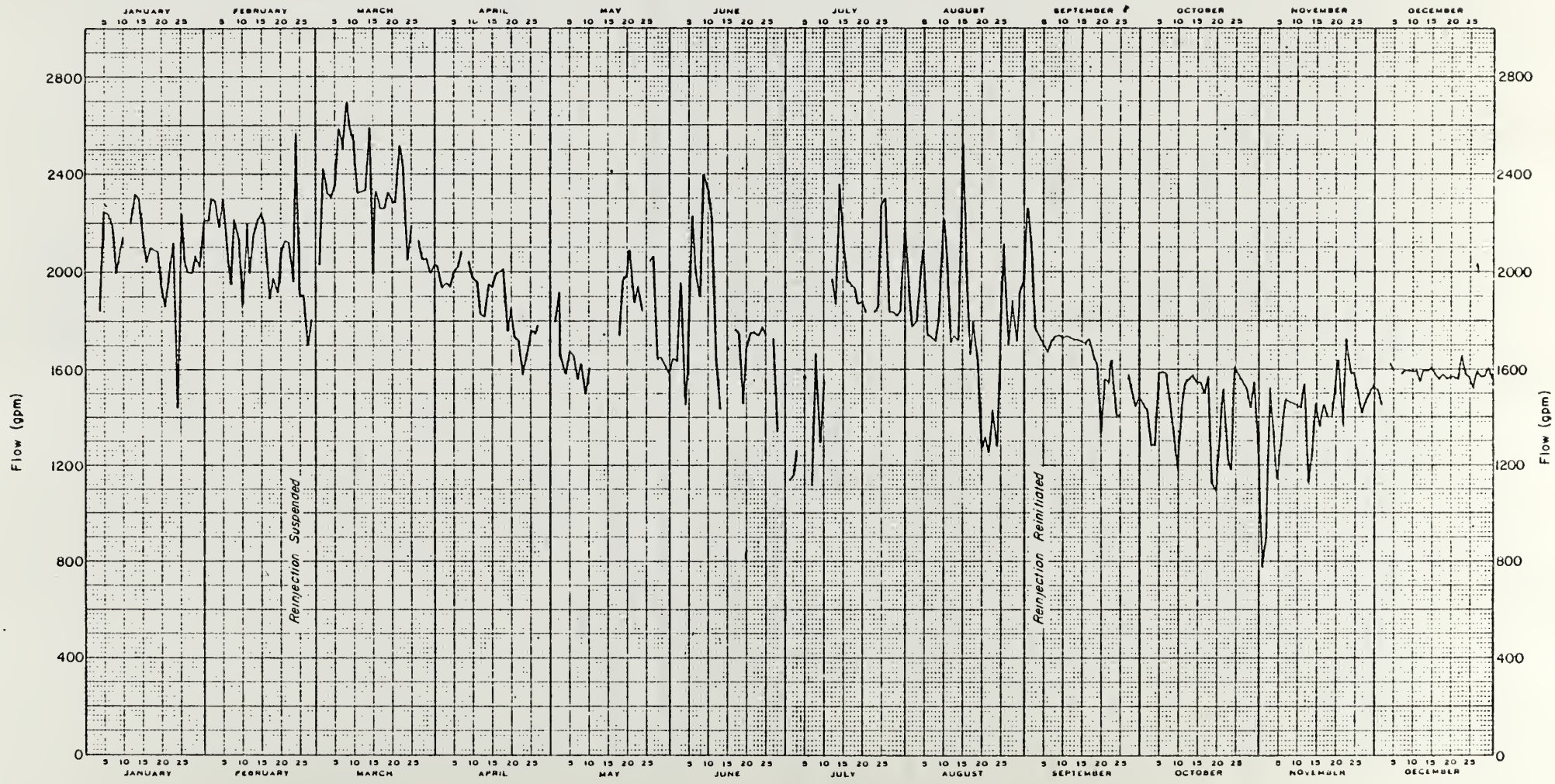
TOTAL WATER DISPOSAL
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)
Reinjection Suspended
Reinjection Reinitiated

Figure 5-198.

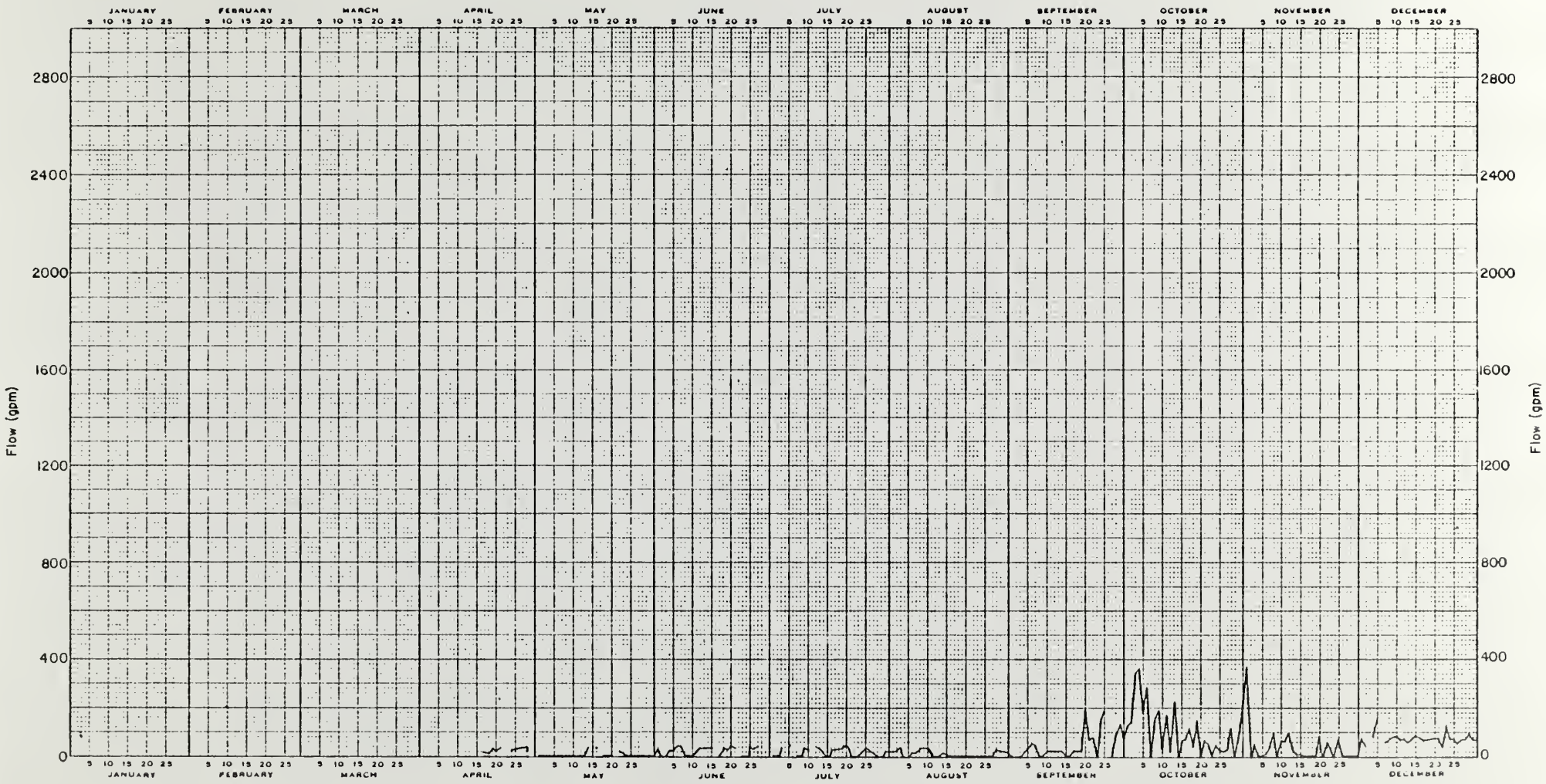
CONSUMPTIVE USE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)

Figure 5-199.

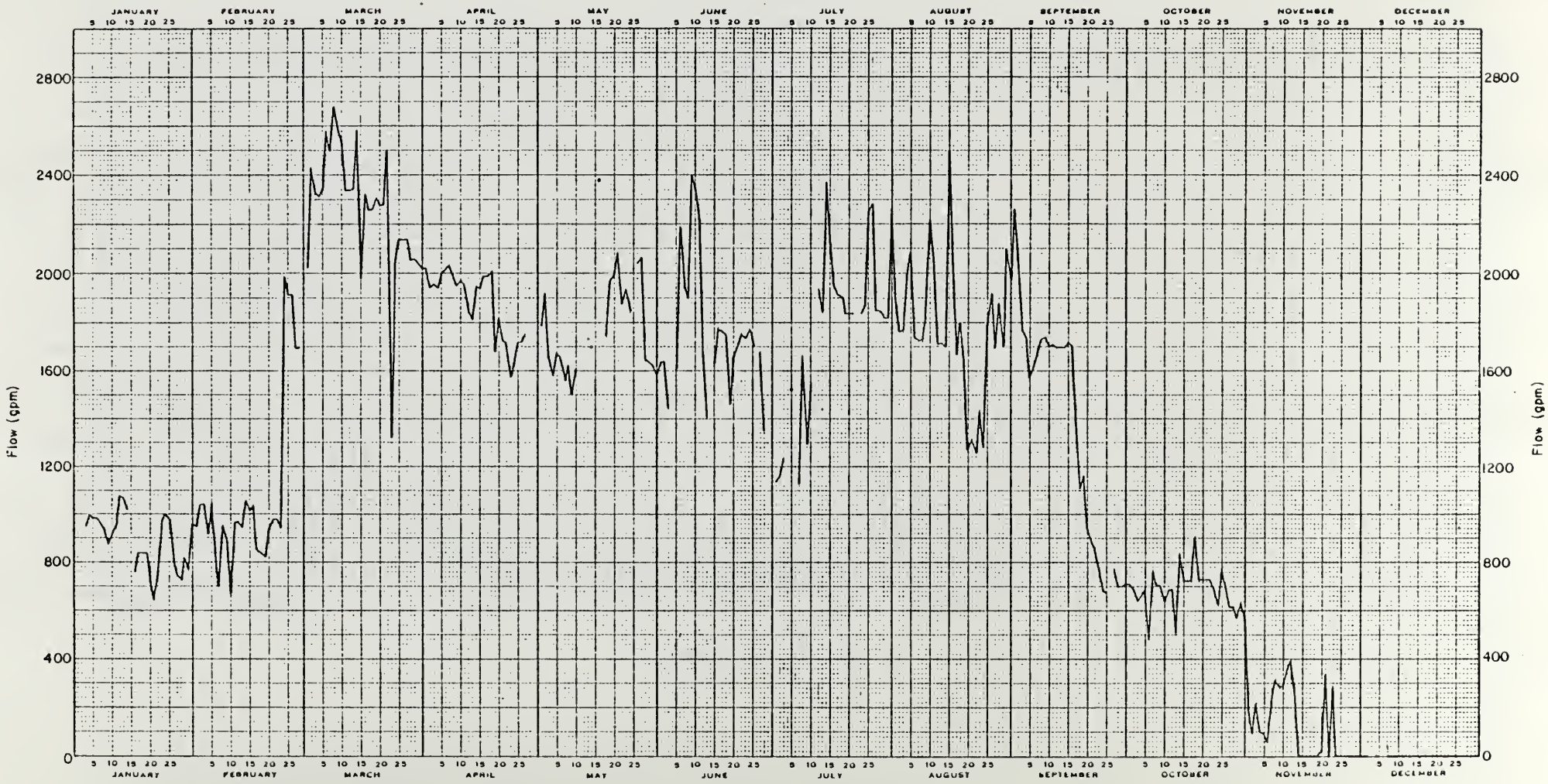
SURFACE DISCHARGE
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)

Figure 5-200.

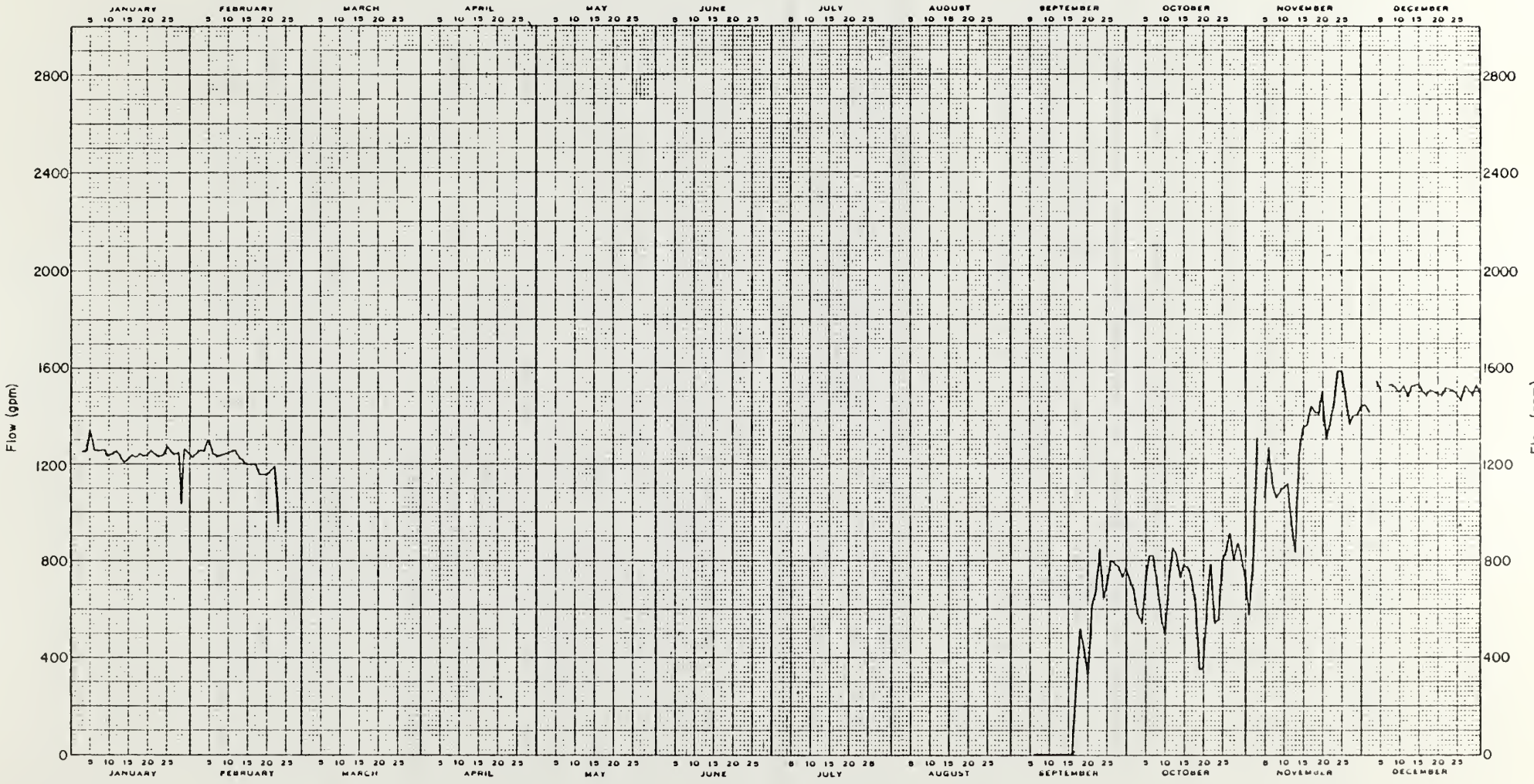
TOTAL REINJECTION
JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
NOVEMBER
DECEMBER
5 10 15 20 25
8 10 15 20 25
8 10 15 20 28
8 10 18 20 25
2800
2400
2000
1600
1200
800
400
0
Flow (gpm)

Figure 5-201.

c. Ponds - Three holding ponds on Tract C-a were utilized for temporary or permanent storage of various effluents associated with the development activities during the reporting period. Mine seepage water was discharged into a Head Frame Pond for initial settling during shaft construction, and the effluent from this pond was pumped into the West Retention Pond. Well production and surface runoff from the mine area were also collected in the West Retention Pond where the water is stored until needed for reinjection, discharge to Corral Gulch, or consumptive use (fire, storage, and drilling water). The East Retention Pond is a holding pond used for sewage blow down and blow down to be produced from future retort operations. When retort operations begin, water from this pond will be pumped to evaporation ponds for disposal.

Plots of physical data for the West Retention Pond are shown in Figures 5-202 through 5-204. During the early part of the monitoring period, the conductivity data fluctuated around a mean of between 1100 and 1200. During the month of September, an apparent increase in conductivity occurred, followed by fluctuations in conductivity around a mean of approximately 1400. This apparent net increase has been attributed to problems with the field conductivity meter used to monitor the ponds during this period. This interpretation is supported by the conductivity values at Corral Gulch being 1400 umhos since discharge began. The short-term fluctuations in conductivity and temperature are considered to be due to fluctuations in pond operations and weather conditions impacting the surface of the pond. Temperature and pH exhibit short-term fluctuations similar to those for conductivity, with the surface temperature showing seasonal fluctuations and the pH remaining relatively constant.

Physical data for East Retention Pond are plotted in Figures 5-205 through 5-207. The plots of these parameters show short-term fluctuations as did the West Retention Pond. East Retention Pond conductivity and temperature also exhibit long-term fluctuations which are similar to those for West Retention

WEST POND CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

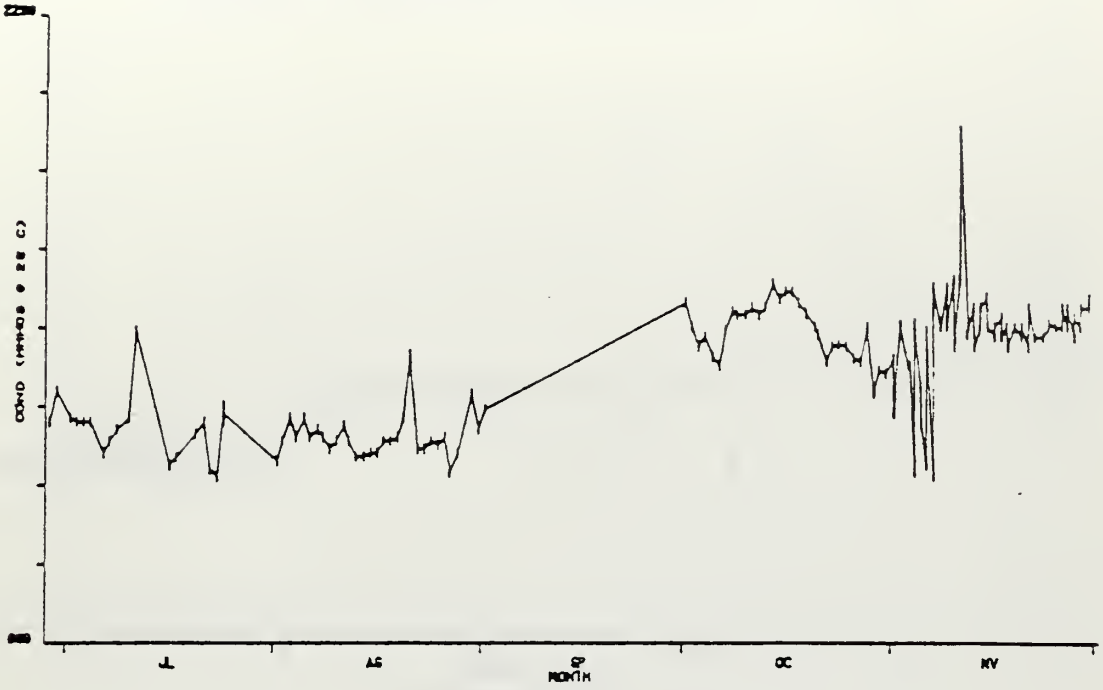

Figure 5-202

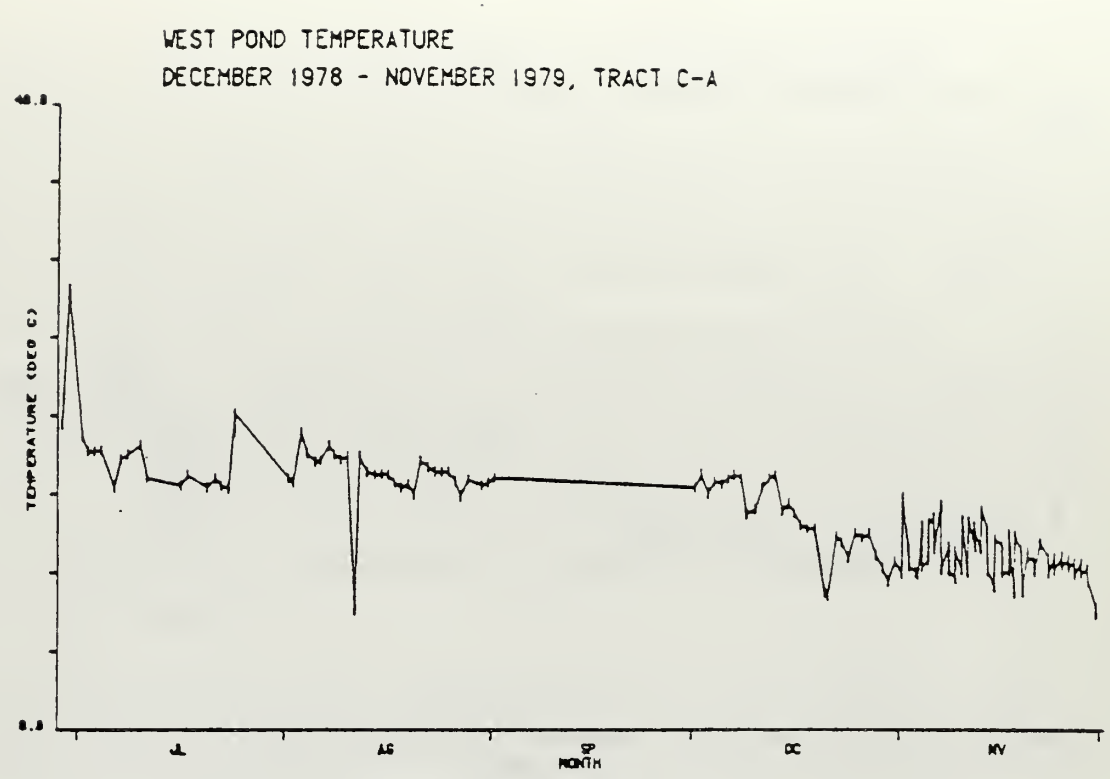

Figure 5-203

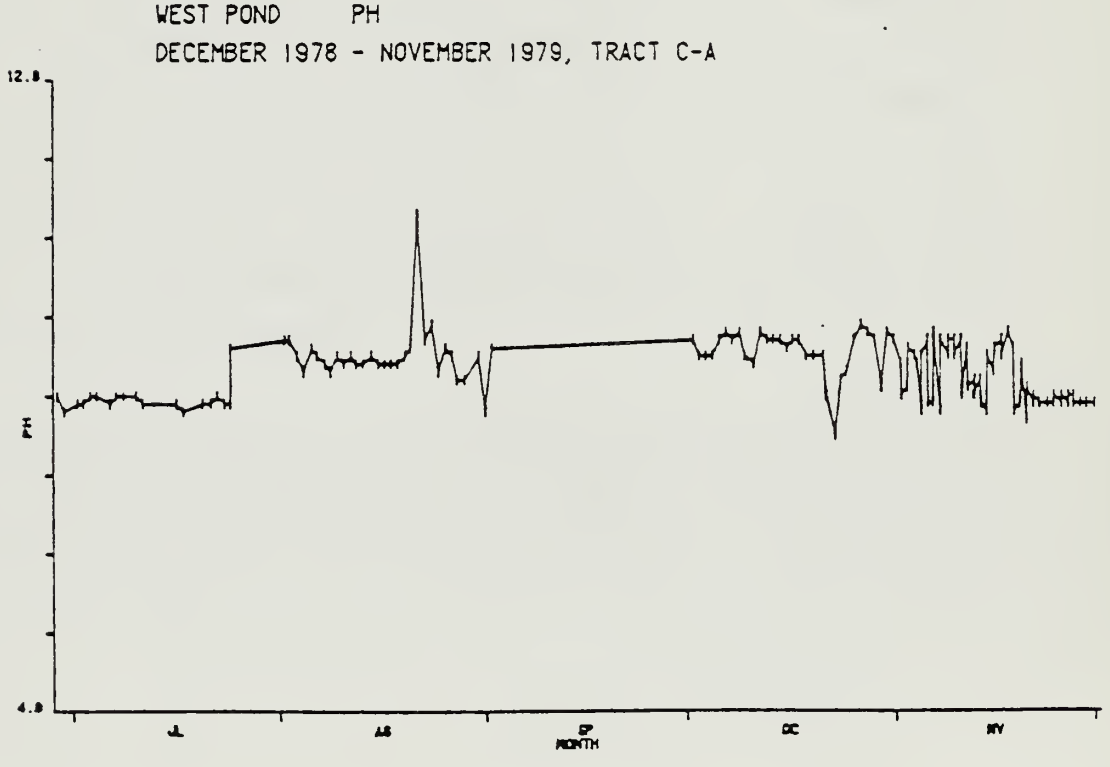

Figure 5-204

EAST POND CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

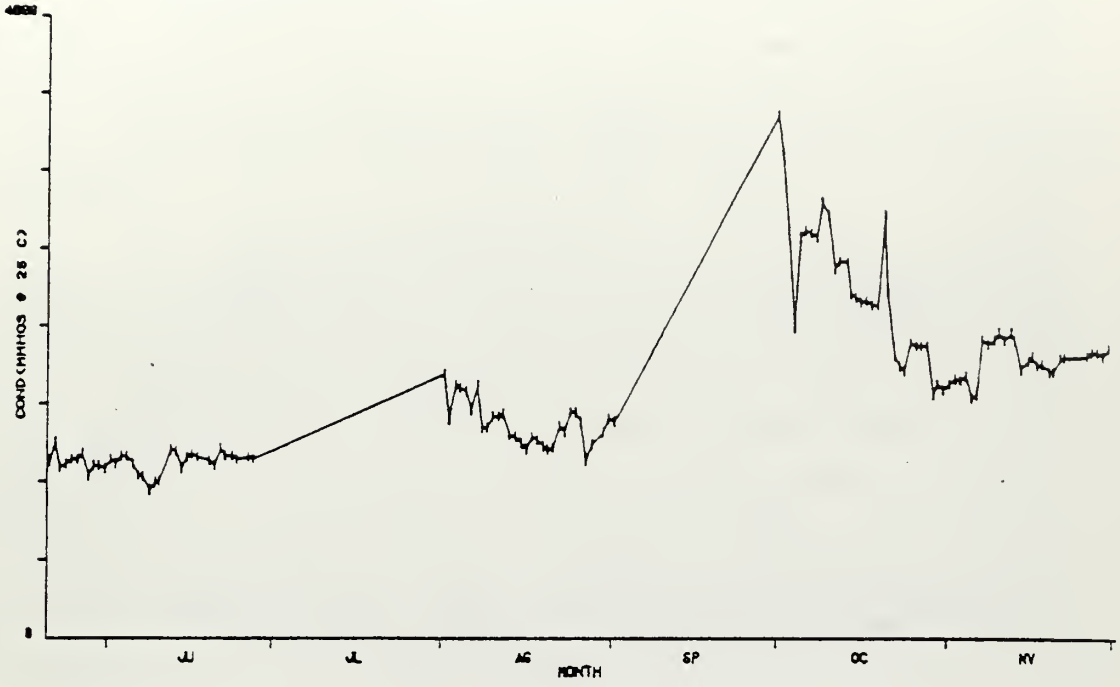

Figure 5-205

EAST POND TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

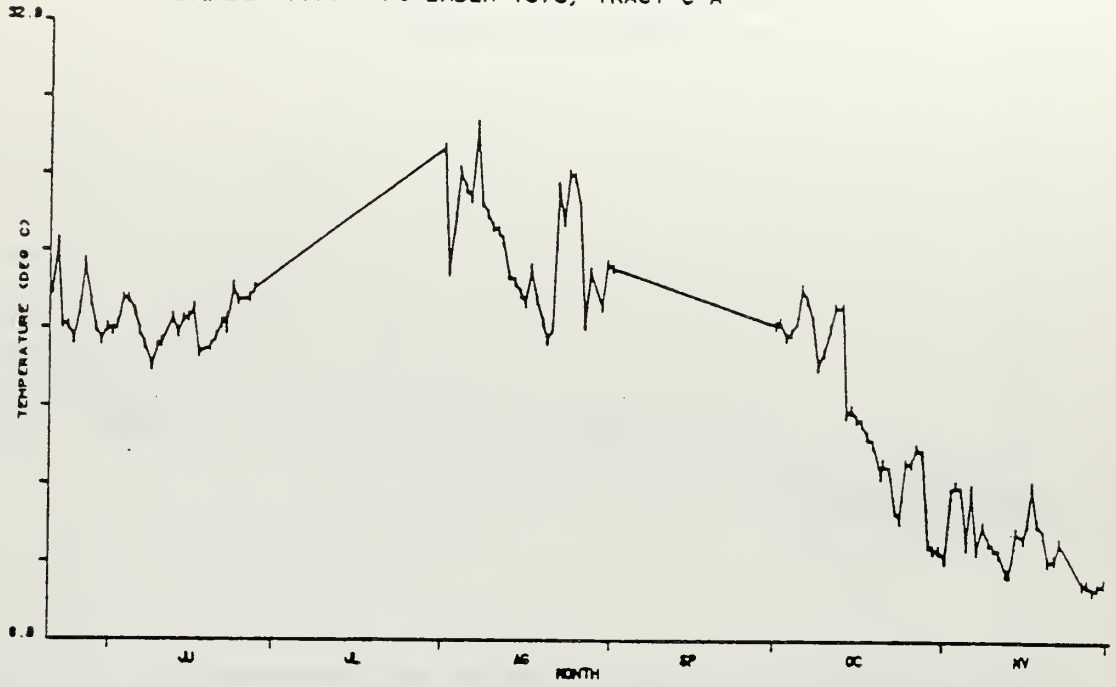

Figure 5-206

EAST POND PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

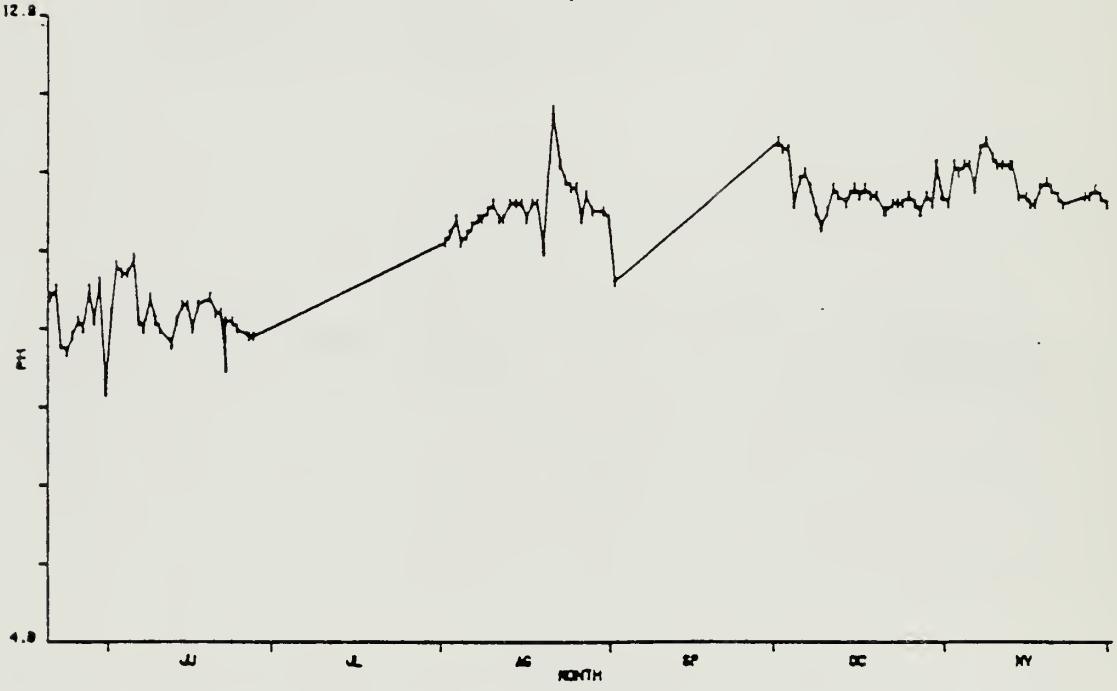

Figure 5-207

Pond, only larger in magnitude. East Retention Pond pH exhibits a slight long-term increase over the monitoring period. At the same time the conductivity meter was repaired, blowdown from the reverse osmosis unit was put in the pond. The surface value of conductivity rose to high levels and decreased as the pond mixed.

Physical data for the Head Frame Pond are plotted in Figures 5-208 through 5-210. These data are available only for June and July. During that time period there is little variation in temperature and pH, but an increase of about 100 micromos during late June, followed by a return to the normal level of about 1080 in early July. This small fluctuation could be due to a temporary change in quality of mine dewatering and seepage water, or it could be due to changed conditions in the pond. Temporary disturbance of settled materials in the pond could account for a short-term rise in conductivity such as this one.

There are two runoff collection ponds on Tract C-a. The West Runoff Pond contained water for part of the year. Physical parameters were measured during this period and are shown in Figures 5-211 through 5-213. Low values of conductivity reflect conductivity meter problems and the high values reflect solids concentration from evaporation. The sharp decrease in October is from a heavy rainfall that diluted the pond. The temperature reflects seasonal fluctuations and the pH fluctuated throughout the period but did not exhibit any trends.

Four piezometers were located, downstream from the East and West Retention Ponds for the purpose of monitoring pond seepage. Water level observations were taken in each of the piezometers during September, October, and November. In September and October, all piezometers were dry, which would indicate no detectable seepage from the ponds. In November, water levels were measured in three of the piezometers; however it was observed at that time that the presence of water in these piezometers was due to precipitation, and did not indicate seepage from any of the ponds.

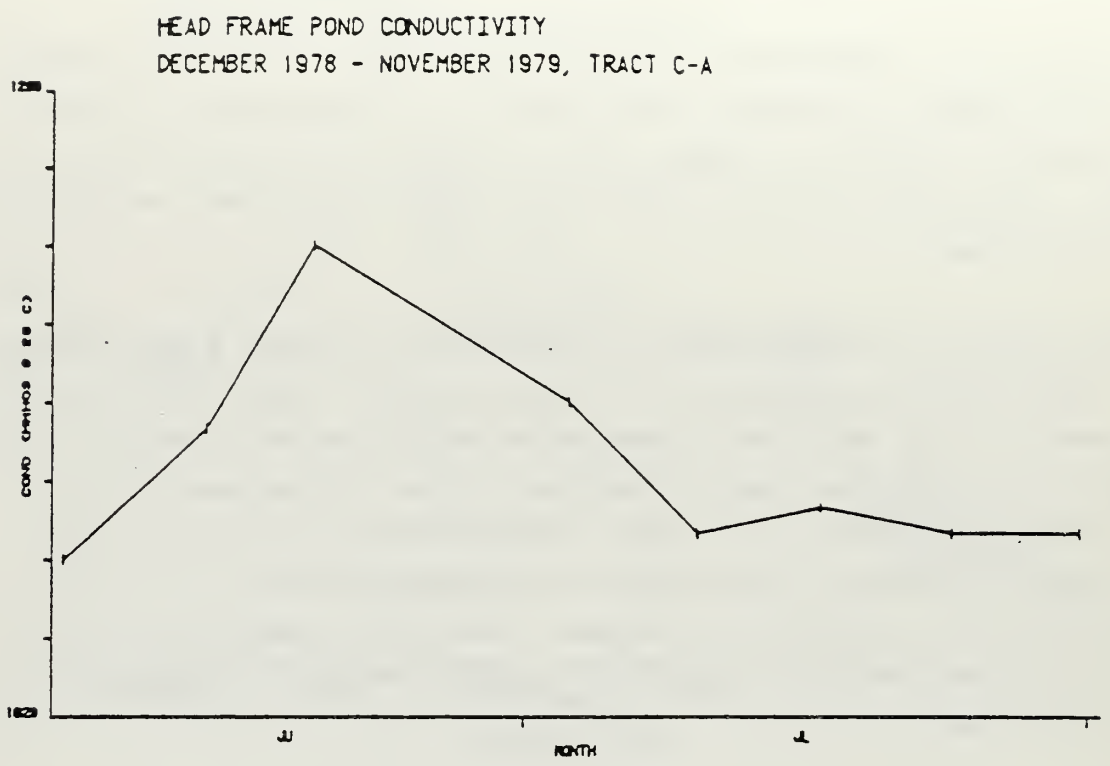
HEAD FRAME POND CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A
MONTH

Figure 5-208

HEAD FRAME POND TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

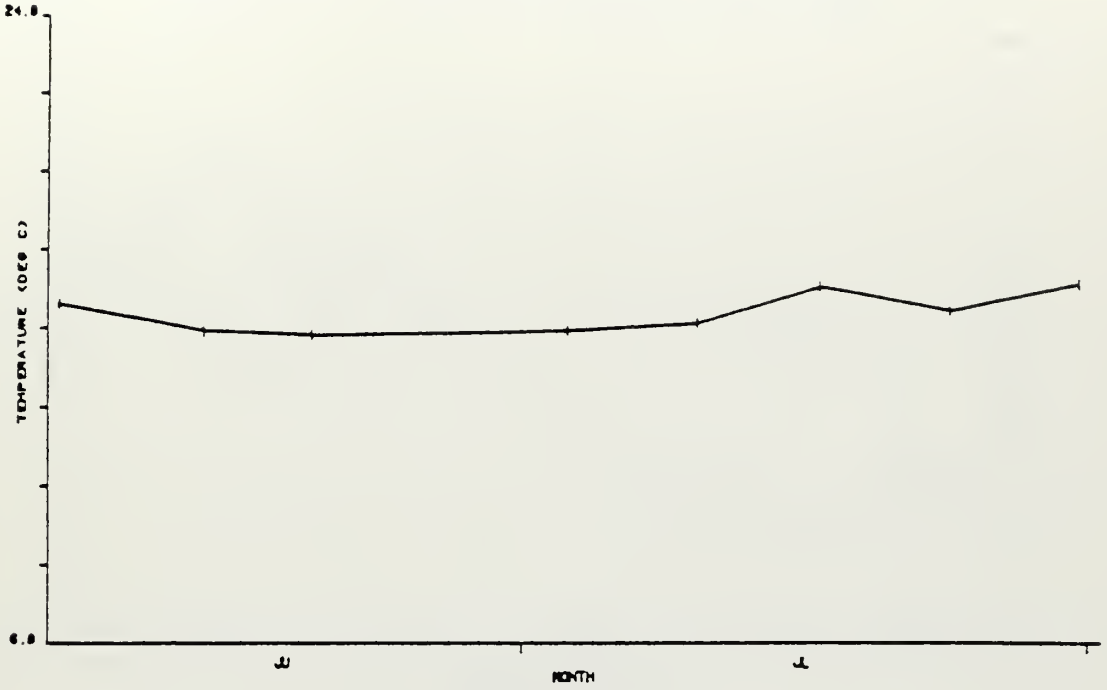

Figure 5-209

HEAD FRAME POND PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

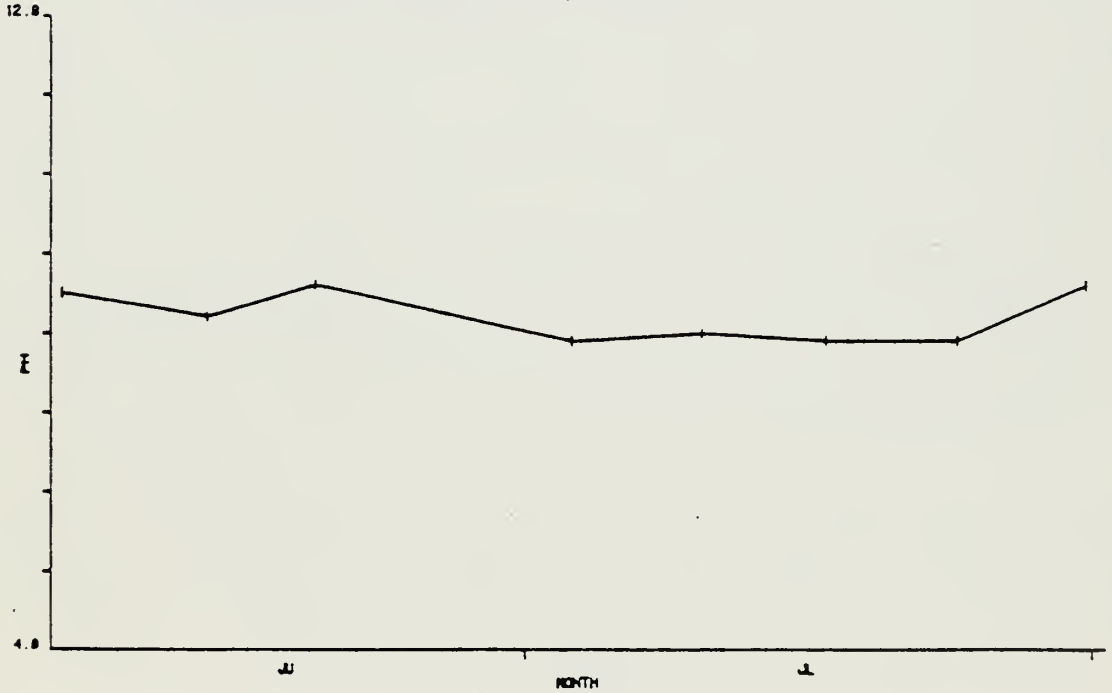

Figure 5-210

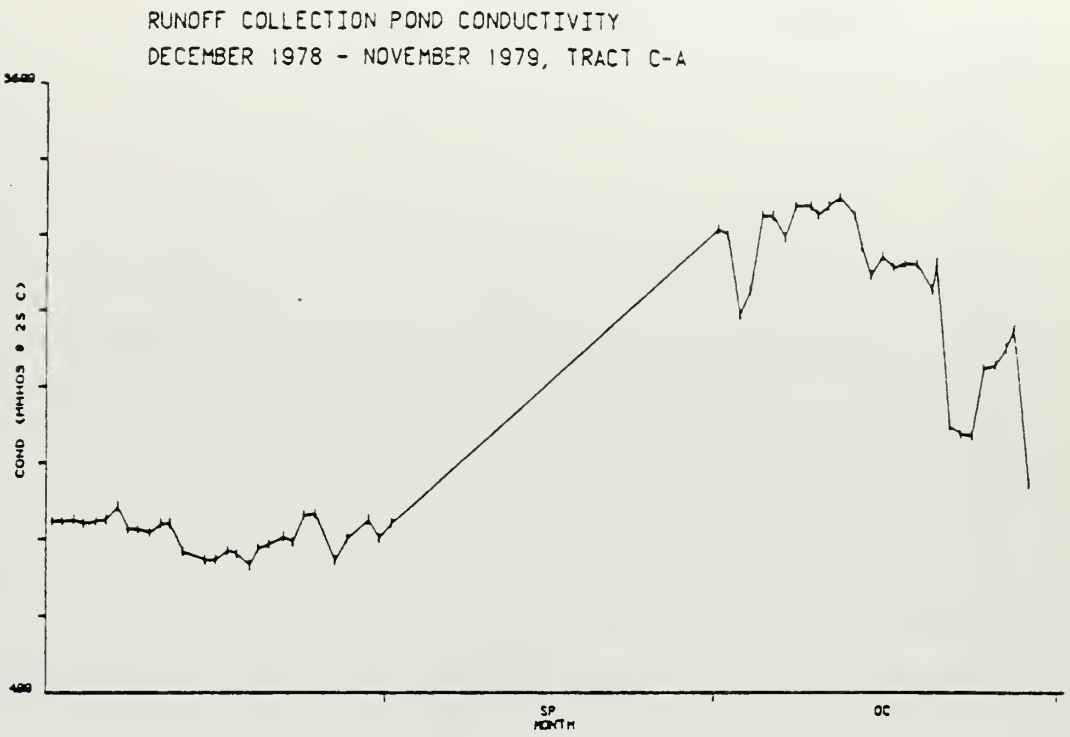
RUNOFF COLLECTION POND CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A
COND (MMHOS @ 25 C)
SP
OC

Figure 5-211

RUNOFF COLLECTION POND TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

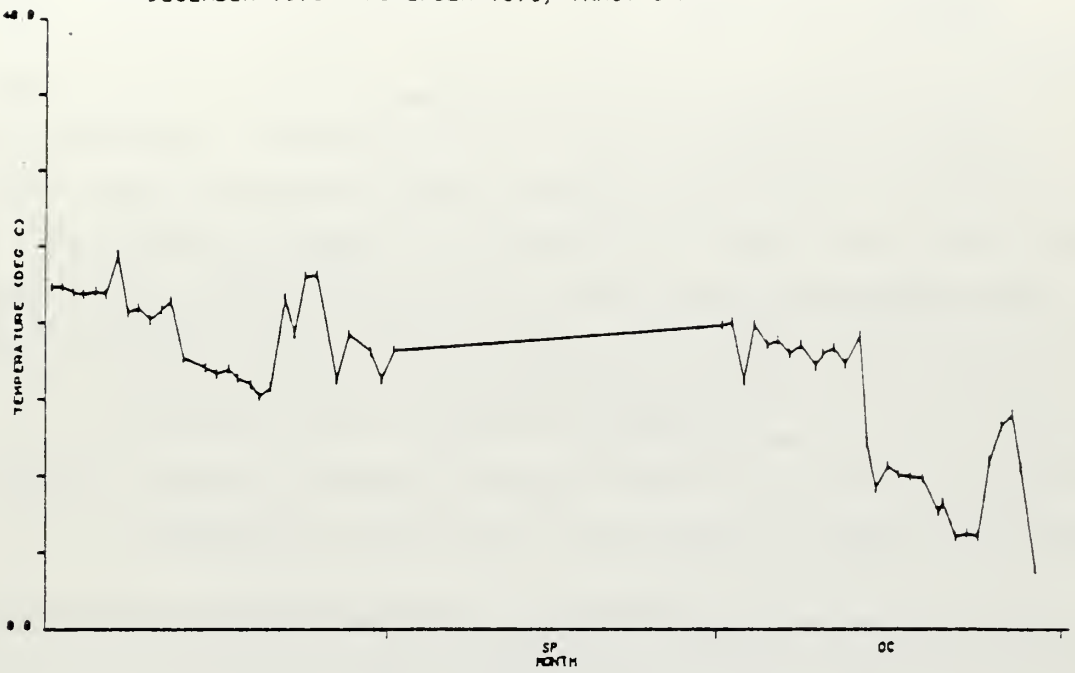

Figure 5-212

RUNOFF COLLECTION POND PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

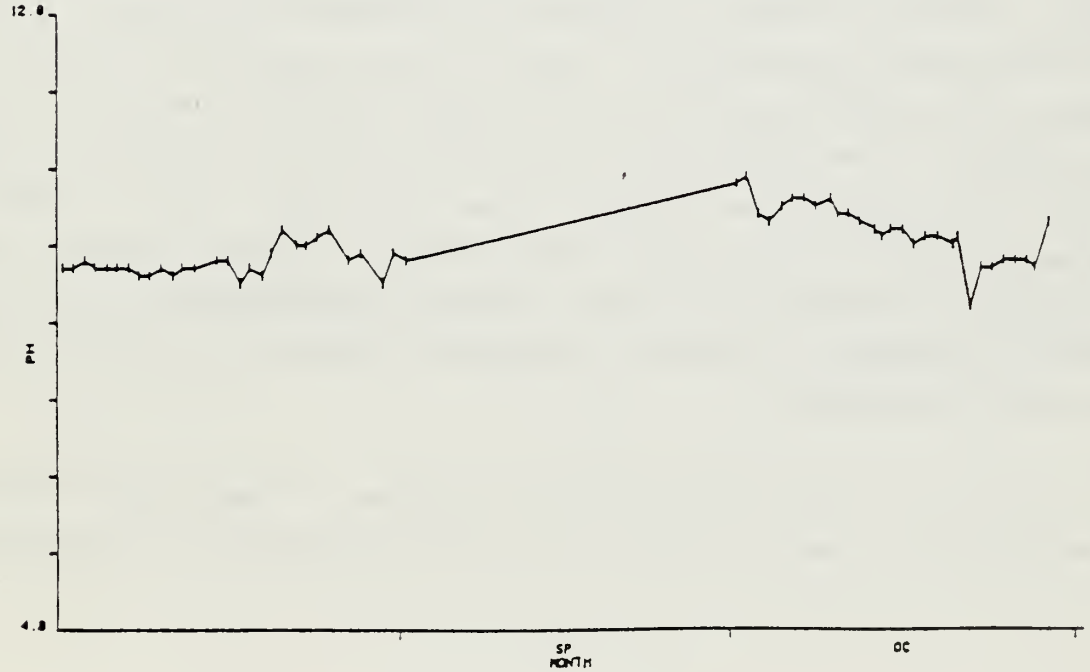

Figure 5-213

d. Composite reinjection - Water was reinjected to the upper aquifer through Wells No. G-S 4-5, G-S 6, TO-2, and TO-3. Physical data for the water which is reinjected through these wells are shown in Figures 5-214 through 5-216. TO-2 was not reinstated to reduce recycling effects. Conductivity shows numerous short-term fluctuations, probably due to the operation West Pond, from which the water is taken. A slight dip in long-term conductivity is seen in late October and early November, but this trend appears to be reversing near the end of the period. The temperature graph also shows numerous short-term fluctuations, superimposed on a long-term decrease in temperature, which is apparently due to normal seasonal fluctuations. The plot of pH shows that this parameter remains relatively constant throughout the reporting period, with short-term fluctuations superimposed.

Two springs that are fed by upper aquifer water are expected to show a response to reinjection into the upper aquifer. Monitoring of flow and physical data in each of these springs was begun in February and continued through the reporting period. Physical data for Box Elder Flume are plotted in Figures 5-217 through 5-220. The hydrographs of the spring measured by the station shows a large peak from April to June, that is primarily a response to spring runoff. This is inferred because the short duration of the peak does not correspond to either the pattern or the duration of the reinjection program. The small increase in baseflow from September to November correlates with reinitiation of reinjection. Conductivities at Box Elder Flume show numerous short-term fluctuations, and also some long-term fluctuations, which may be seasonal. The fluctuations in the fall could also indicate a change in water quality due to the increase in flow from higher reinjection pressure. Temperature profile for Box Elder Flume indicates a relatively normal seasonal fluctuation with numerous short-term fluctuations superimposed on it. The graph of pH indicates an apparent rise beginning about the end of July, with short-term fluctuations.

Plots of physical data for Miller Spring are shown in Figures 5-221 through 5-224. Miller Spring has a very low flow rate, and the fluctuations on the hydrograph

COMPOSITE REINJECTION, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

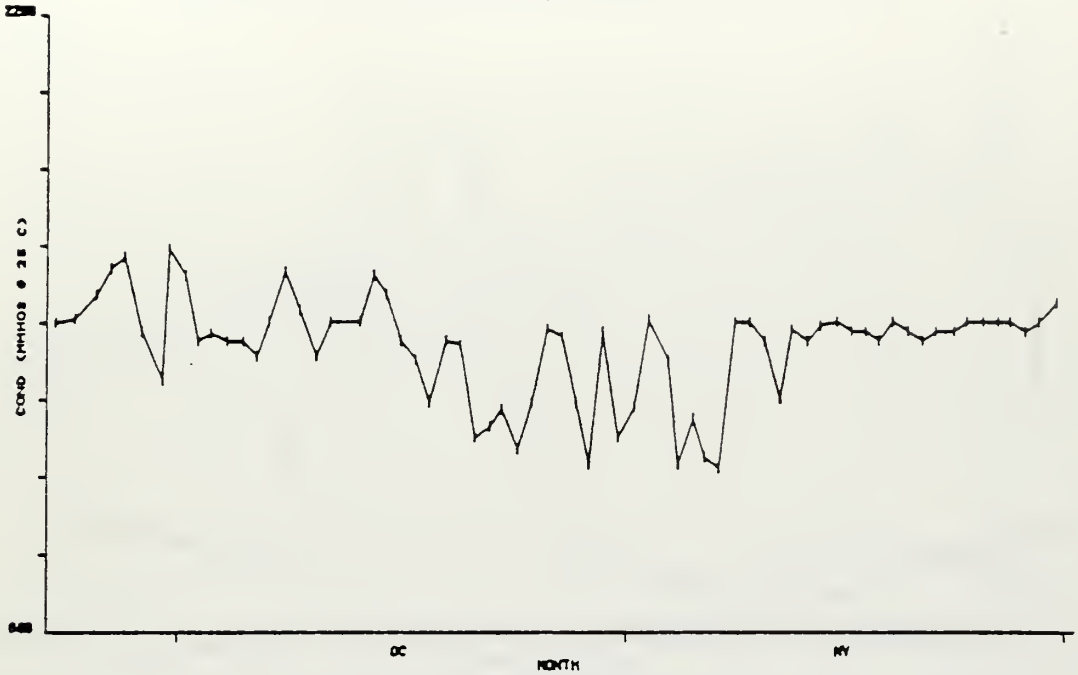

Figure 5-214

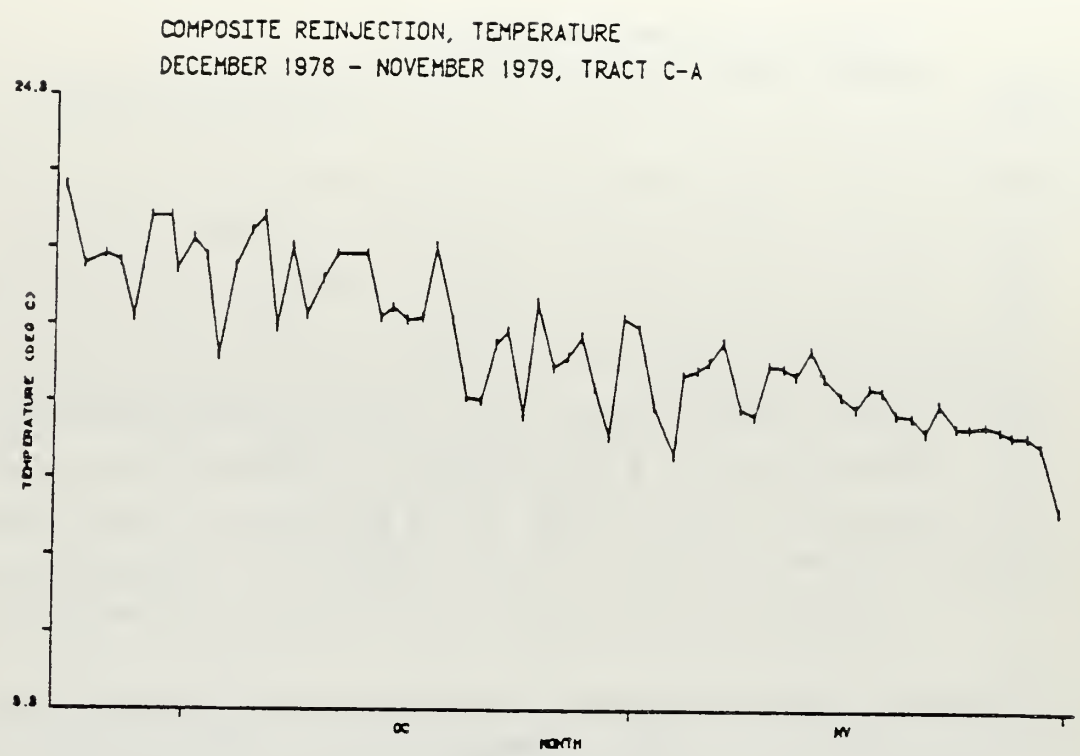

Figure 5-215

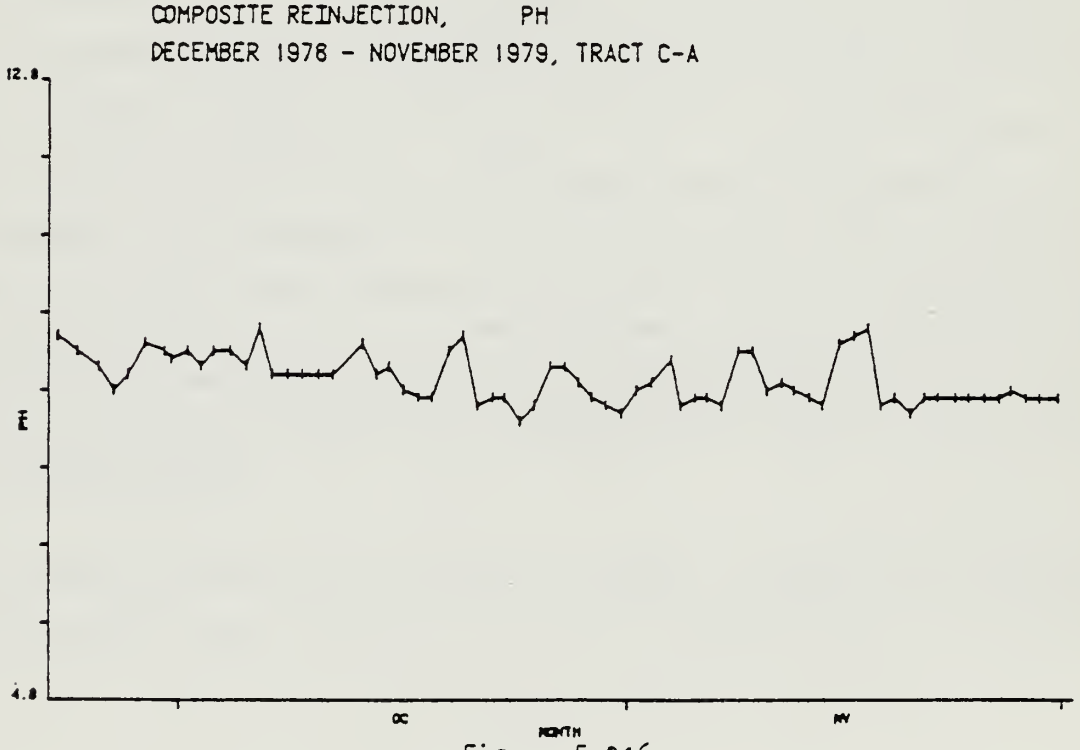

Figure 5-216

BOX ELDER FLUME, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

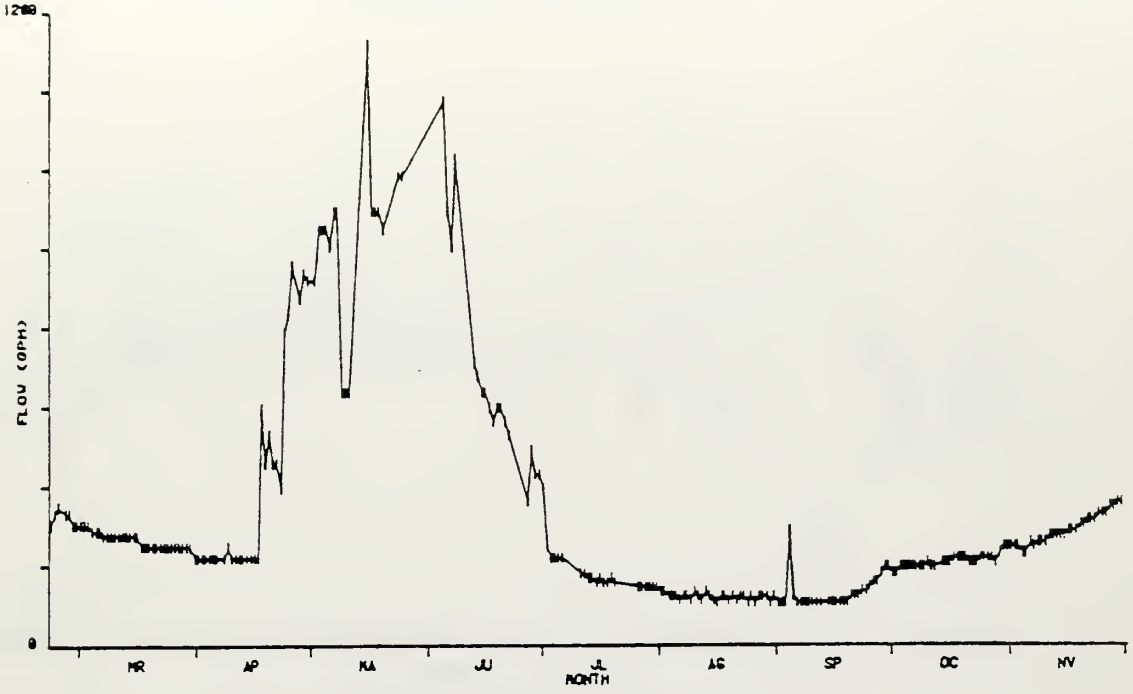

Figure 5-217

BOX ELDER FLUME, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

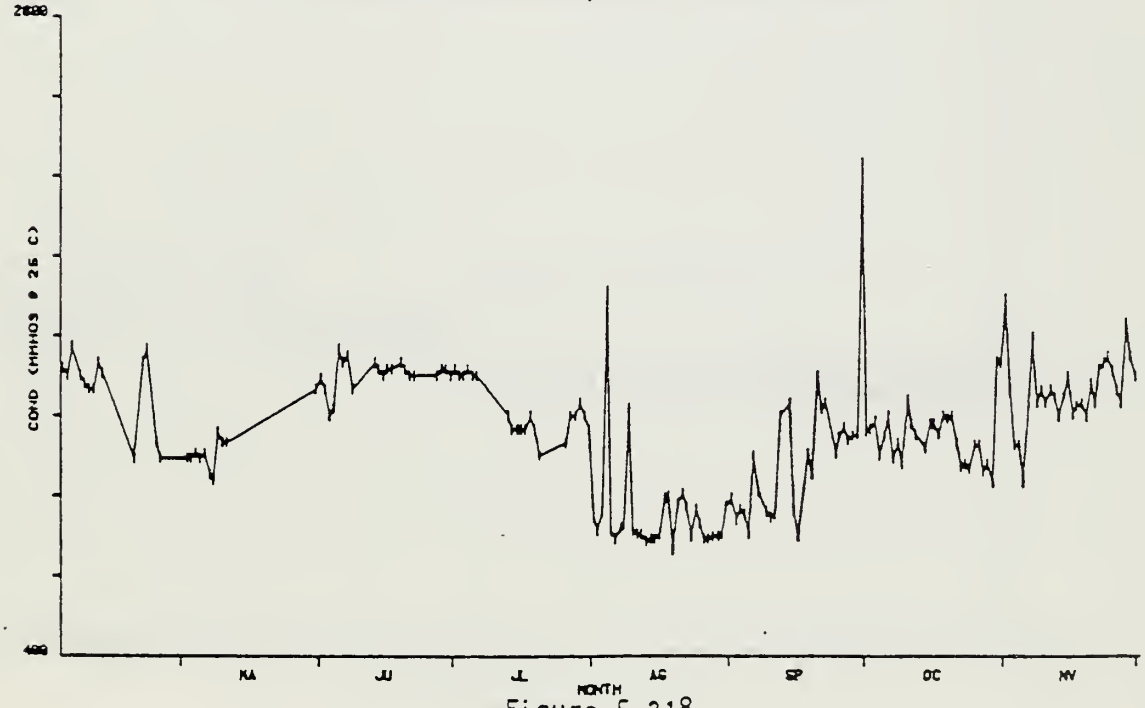

Figure 5-218

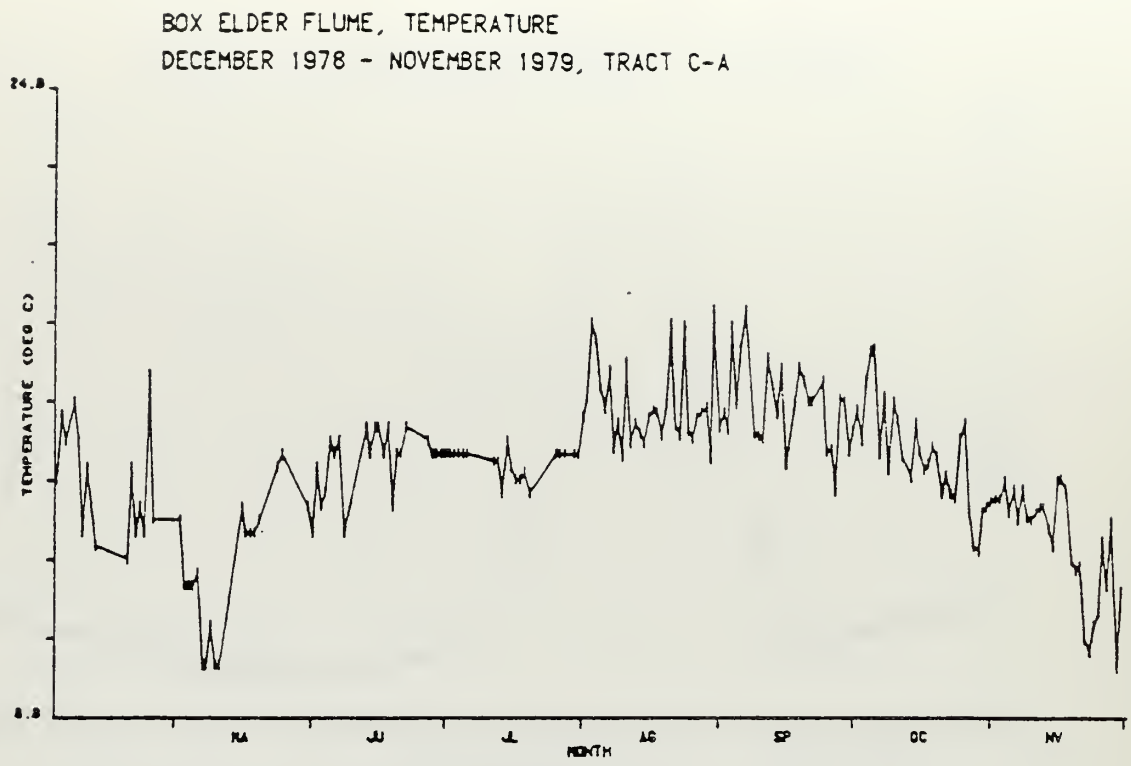

Figure 5-219

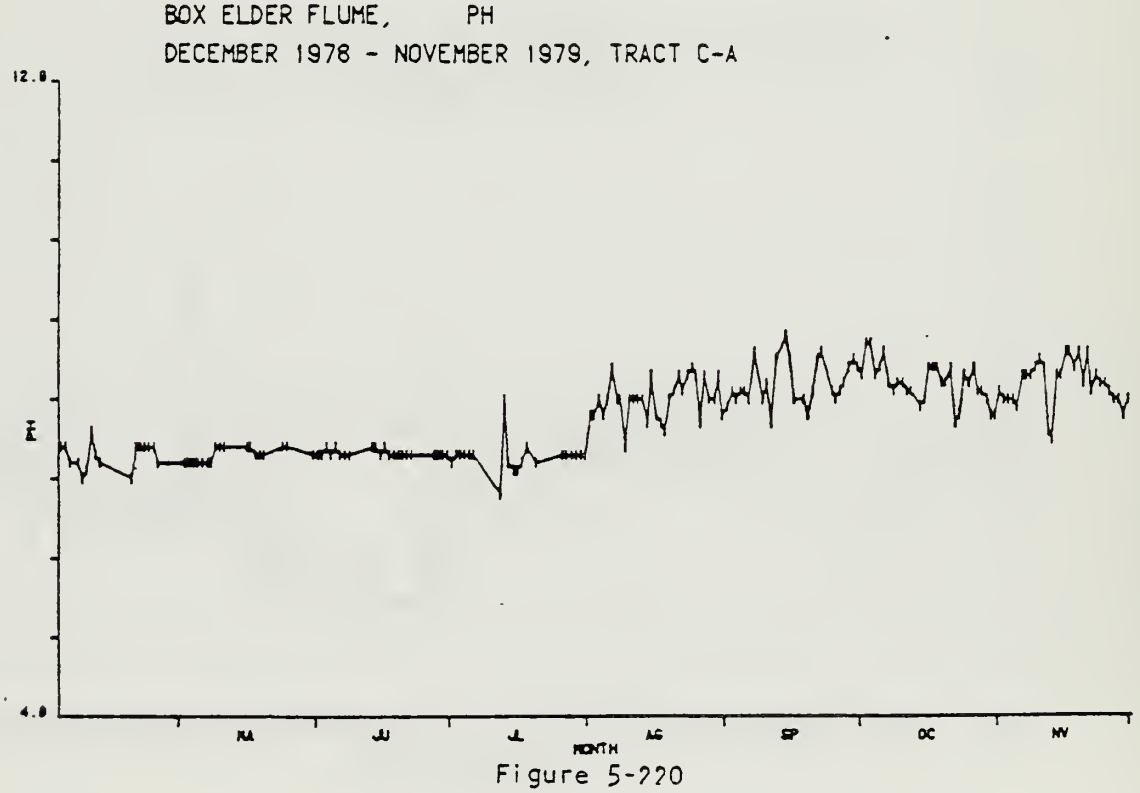

Figure 5-220

MILLER SPRING, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

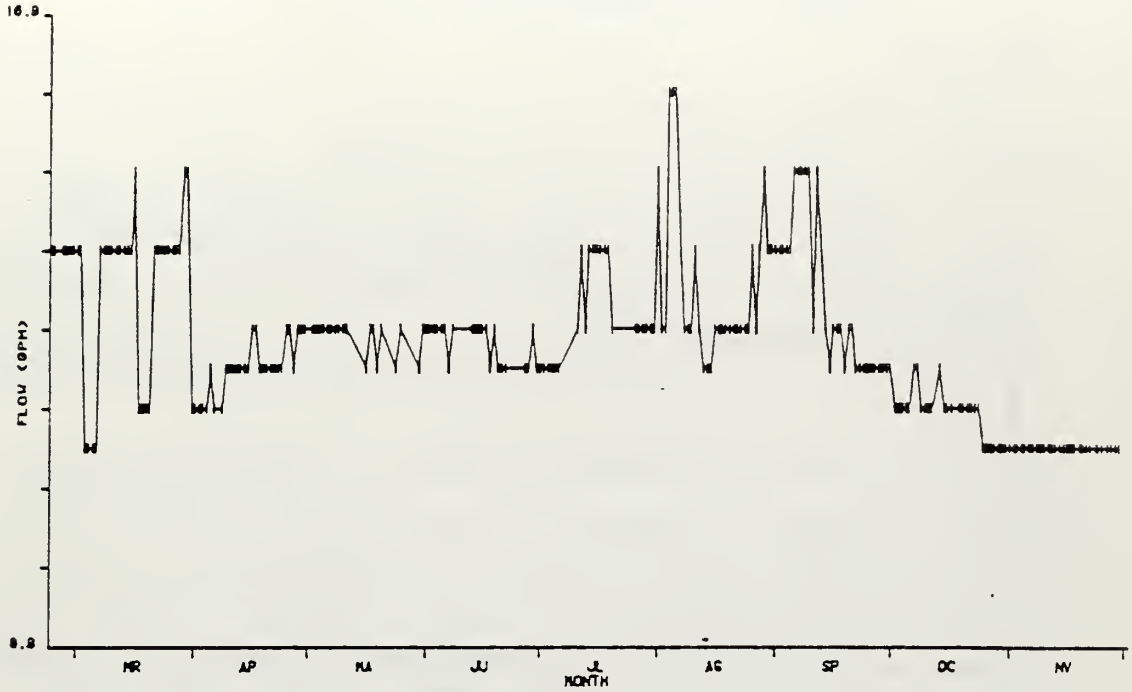

Figure 5-221

MILLER SPRING, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

Figure 5-222

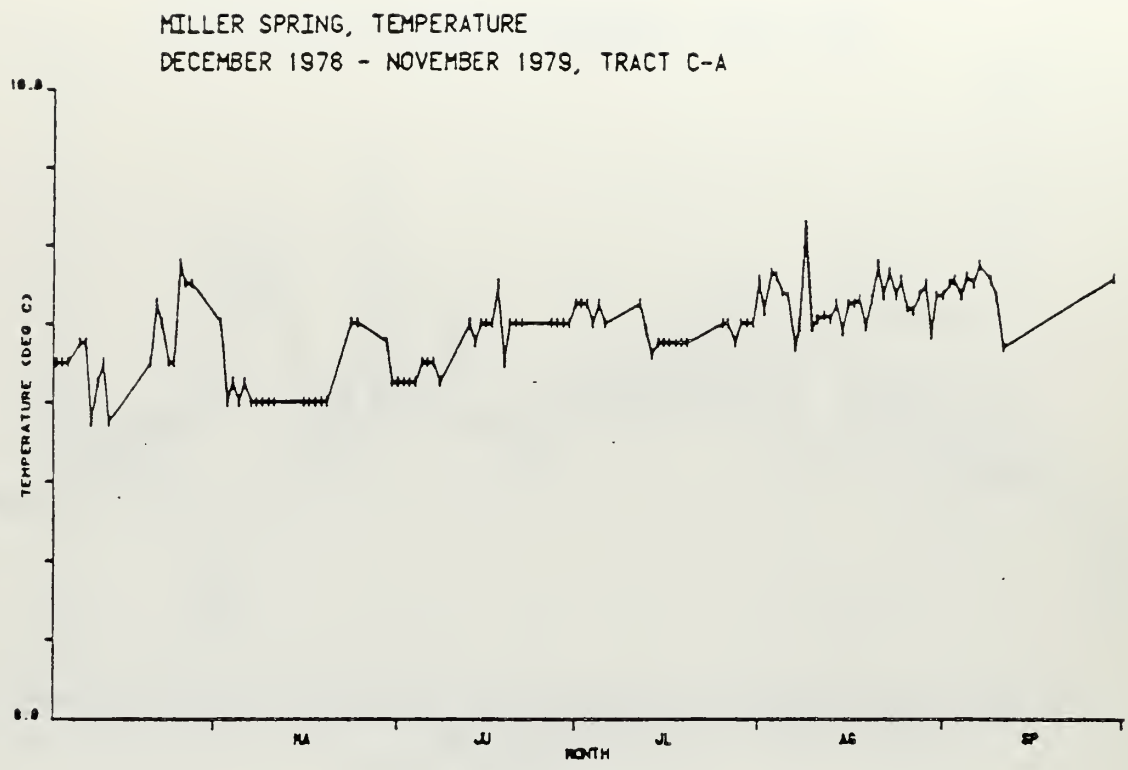

Figure 5-223

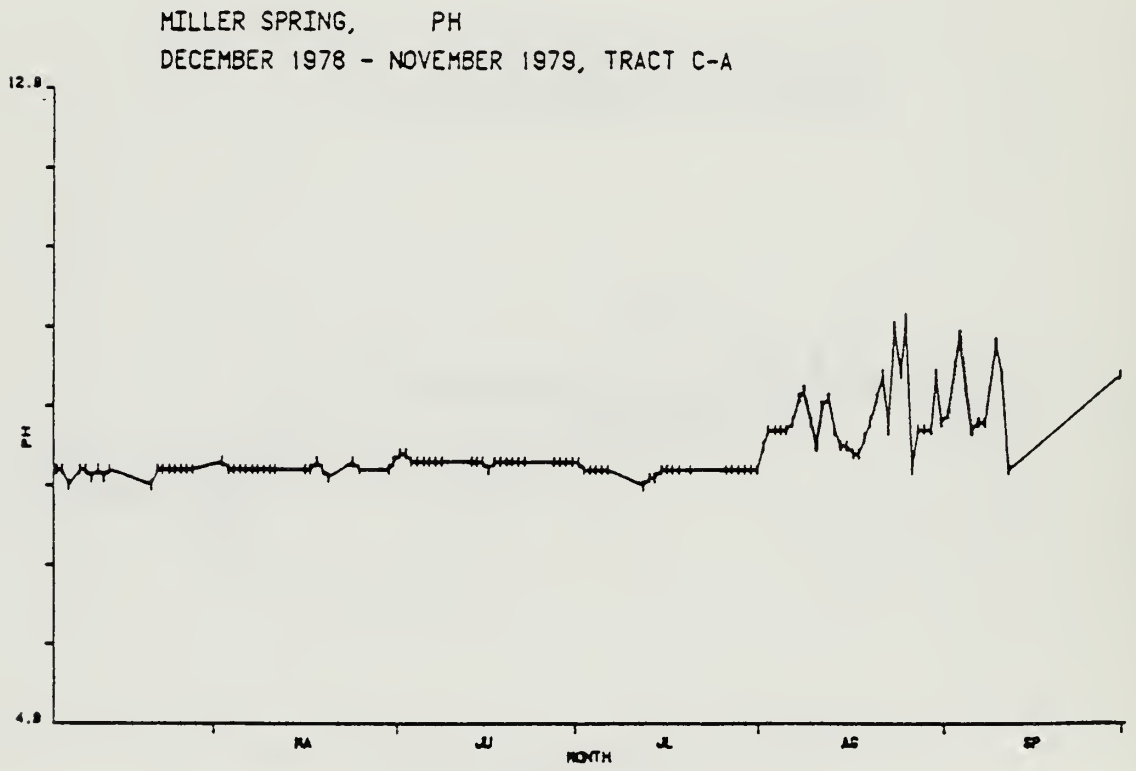

Figure 5-224

may be due to the level of precision of measurement, as well as actual fluctuations. A slight decrease in flow from the beginning to the end of the reporting period is noted. Conductivity for Miller Spring shows a decreasing trend, with short-term fluctuations superimposed. Temperature shows a slight increase from April to September, also with short-term fluctuations. pH is relatively steady from April through July, then in August shows a slight rise combined with short-term fluctuations. The data from Miller Spring do not show an impact from the increased reinjection pressure.

e. Discharge monitoring - A series of monitoring stations are located on Corral Gulch to monitor stream flow, including excess dewatering discharge. Overflow from the West Retention Pond is measured at the flume where it enters Corral Gulch. Regular discharge is piped to the culvert near the Visitors Center at the East Tract Boundary where there is another monitoring station. Further downstream, Station MET 3 is located at U.S.G.S. Station D. The SEO flume, maintained by the State Engineer's Office, located just upstream from 24-Road Crossing, was monitored. At 24-Road Crossing there is a double culvert and a crest stage recorder; all three of these were monitored until November at which time 24-Road Crossing North was diverted to 24-Road Crossing South and 24-Road Crossing North was discontinued.

Conductivity, temperature, and pH for the West Retention Pond flume to Corral Gulch are shown in Figures 5-225 through 5-227. The physical parameters at the flume reflect West Retention Pond conditions.

Conductivity, temperature, and pH for the Corral Gulch culvert system are shown in Figures 5-228 through 5-230. The conductivity is dominated by the discharge as shown by the similarity to the West Retention Pond conductivity; the decrease in October can be attributed to the rains that occurred in October causing a dilution effect. The plot of temperature shows a number of short-term fluctuations. The long-term trend is considered to reflect normal seasonal trend. The graph of pH also shows a number of short-term fluctuations, but on the long-term, remains relatively constant around a value of 8.

FLUME CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

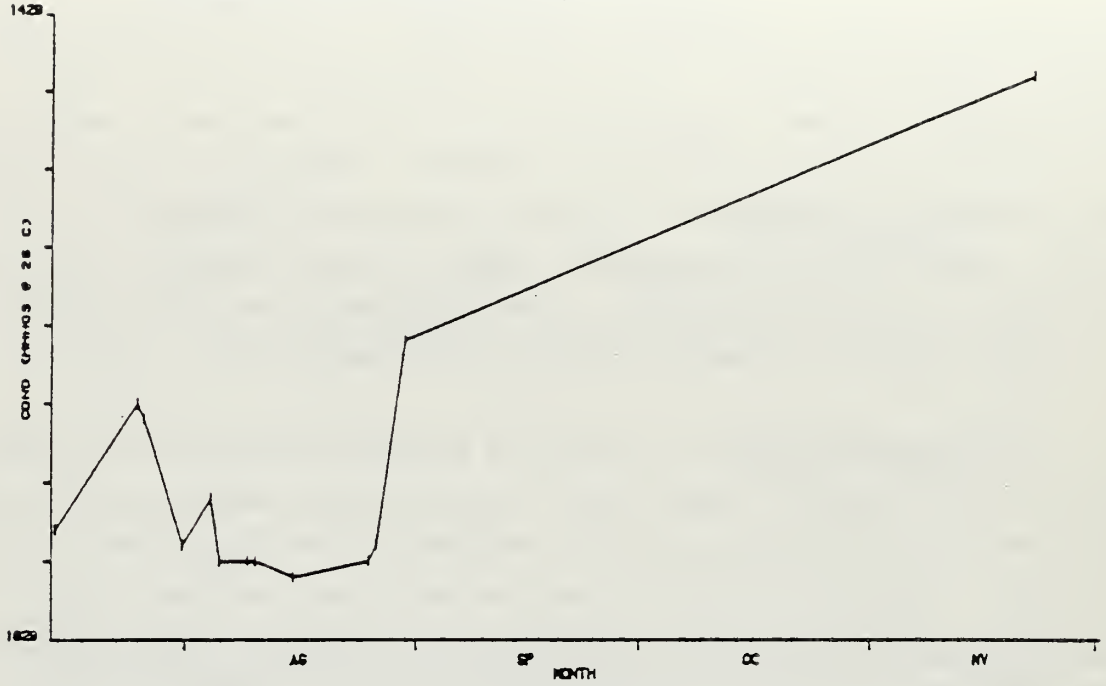

Figure 5-225

FLUME TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

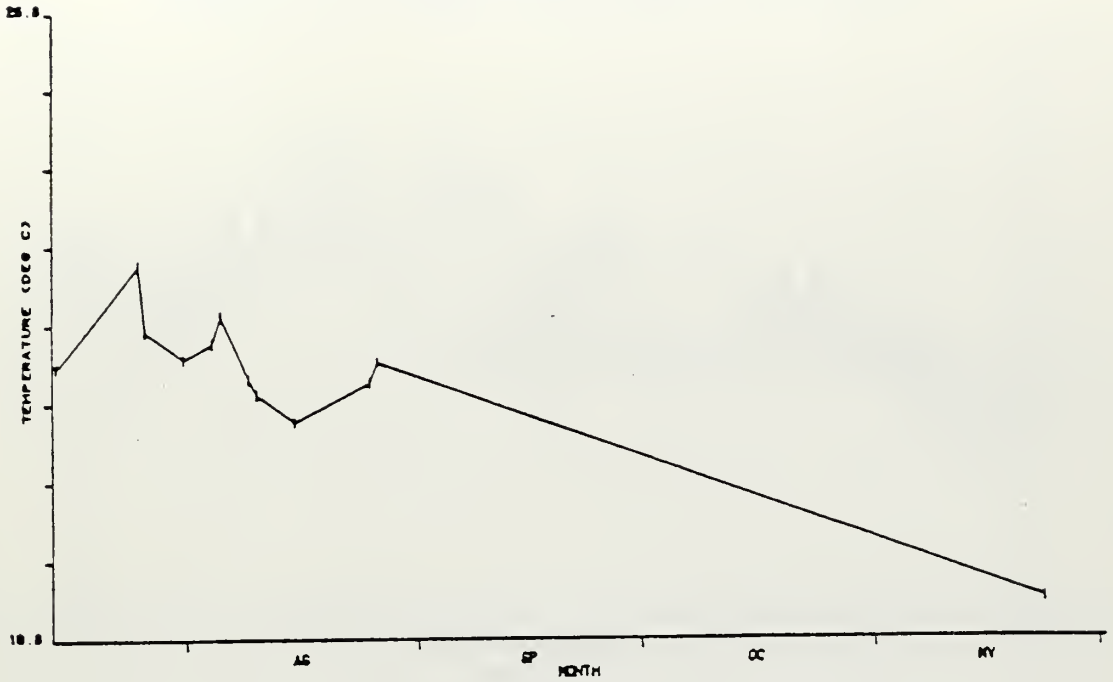

Figure 5-226

FLUME PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

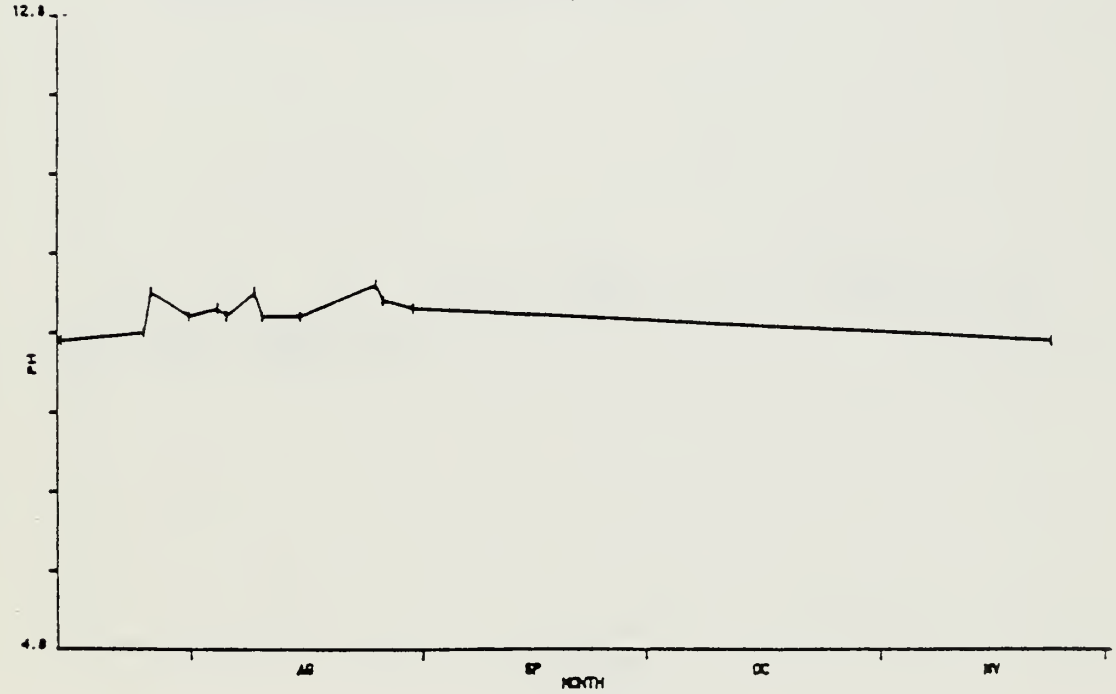

Figure 5-227

CORRAL GULCH CULVERT SYSTEM, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

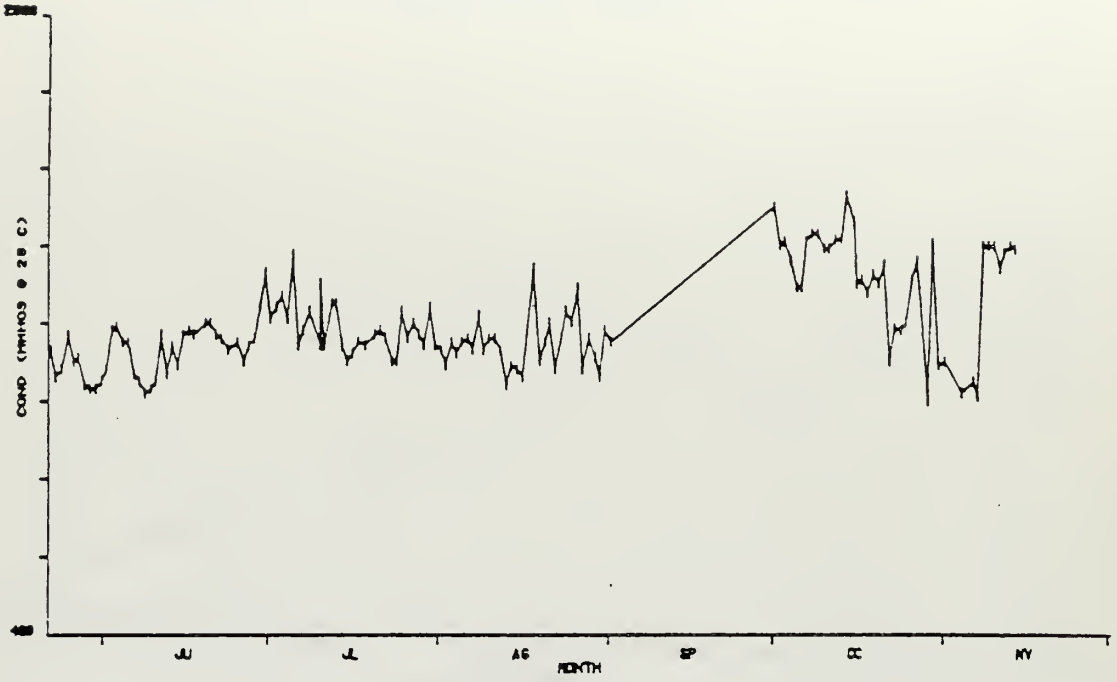

Figure 5-228

CORRAL GULCH CULVERT SYSTEM, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

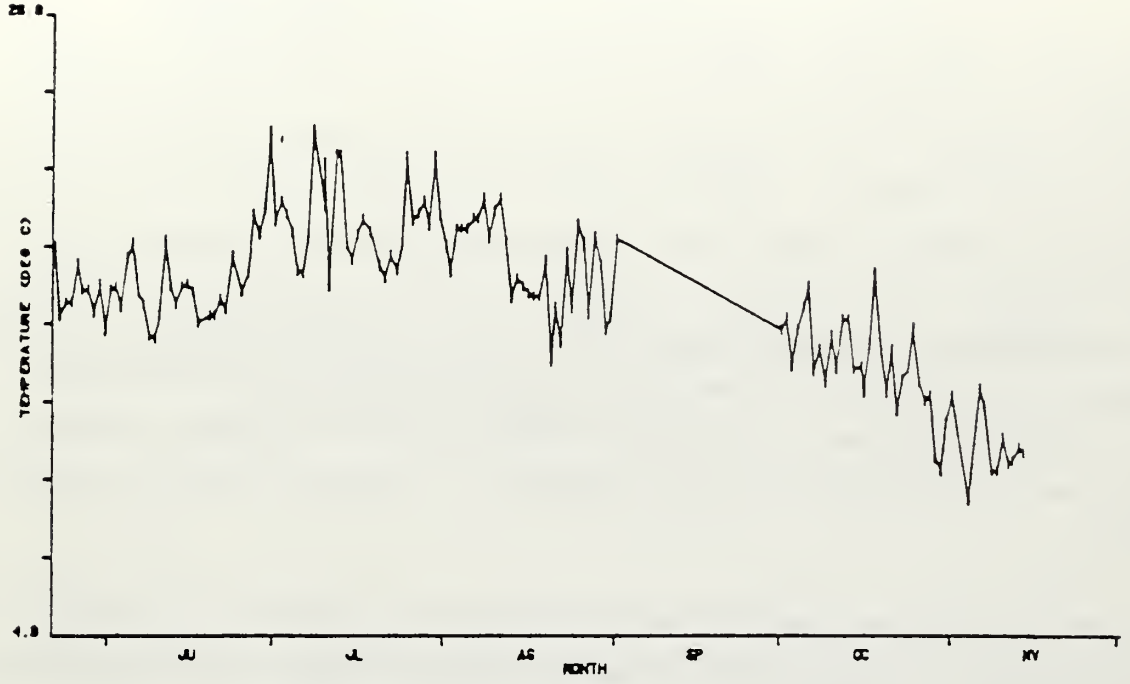

Figure 5-229

CORRAL GULCH CULVERT SYSTEM, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

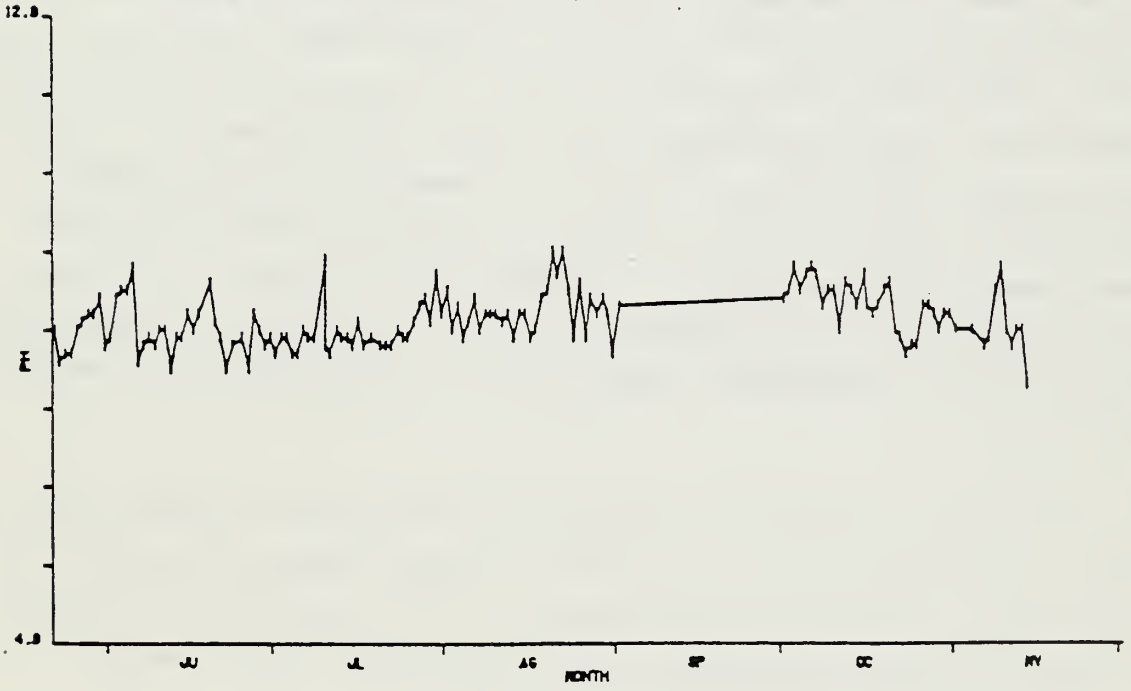

Figure 5-230

MET No. 3 is the U.S.G.S. monitoring Station D and is called MET 3 to distinguish results from U.S.G.S. data. Daily flows for this station are reported in Appendix 5-1.1. Graphs of conductivity, temperature, and pH are shown for this station in Figures 5-231 through 5-233. The graph of conductivity indicates a number of short-term fluctuations, which are characteristic of flows in Corral Gulch. There is a large fluctuation at the end of October and the beginning of November, but there is no long-term trend toward change apparent from these data. Temperature and pH plots also show the typical short-term fluctuations, with temperature declining in a normal seasonal trend, and pH remaining relatively constant at a value of slightly greater than 8.

The physical data for the SEO Flume are plotted in Figures 5-234 through 5-237. The hydrograph for this station shows a combined response to discharge and runoff. Flows increase gradually from February through May as a result of increased discharge. The peak in late May and early June is a result of surface runoff added to the baseflow from discharge. In late June, baseflows decreased as some discharge was diverted to SIR Gulch. The flow has decreased gradually since then as Corral Gulch discharge has been reduced to almost zero since September. The plot of conductivity indicates considerable short-term fluctuations, but only one significant fluctuation of any length. This occurs in the form of a drop in the mean conductivity of about 600 micromos. After mid-September, the conductivity returns to its previous level of about 2200 micromos. The plot of temperature exhibits numerous short-term fluctuations around the long-term seasonal trend with highest temperatures in July and August. The graph of pH indicates a relatively constant value until the beginning of August. At this time, the magnitude of the short-term fluctuations becomes greater and the mean pH increases to about 8.

The physical data for 24-Road Crossing North are shown on Figures 5-238 through 5-241. The hydrograph for this station indicates numerous short-term fluctuations and a slight rise until early July. Four data points in September and October indicate a substantial rise in the water levels; however this

MET #3 CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

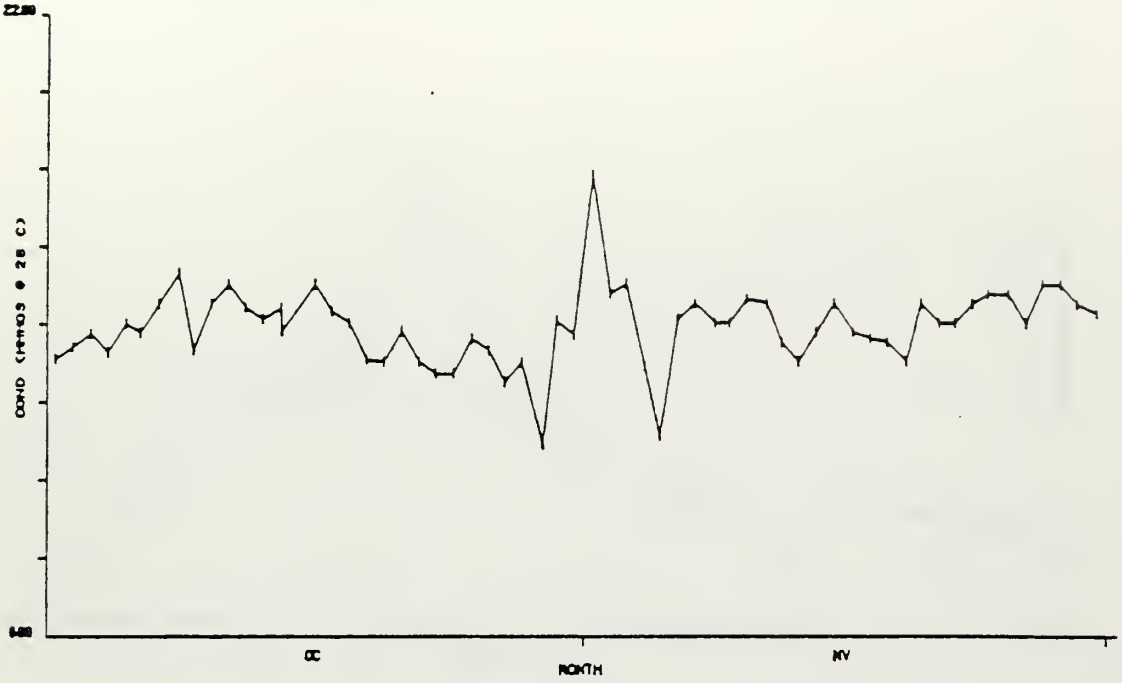

Figure 5-231

MET #3 TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

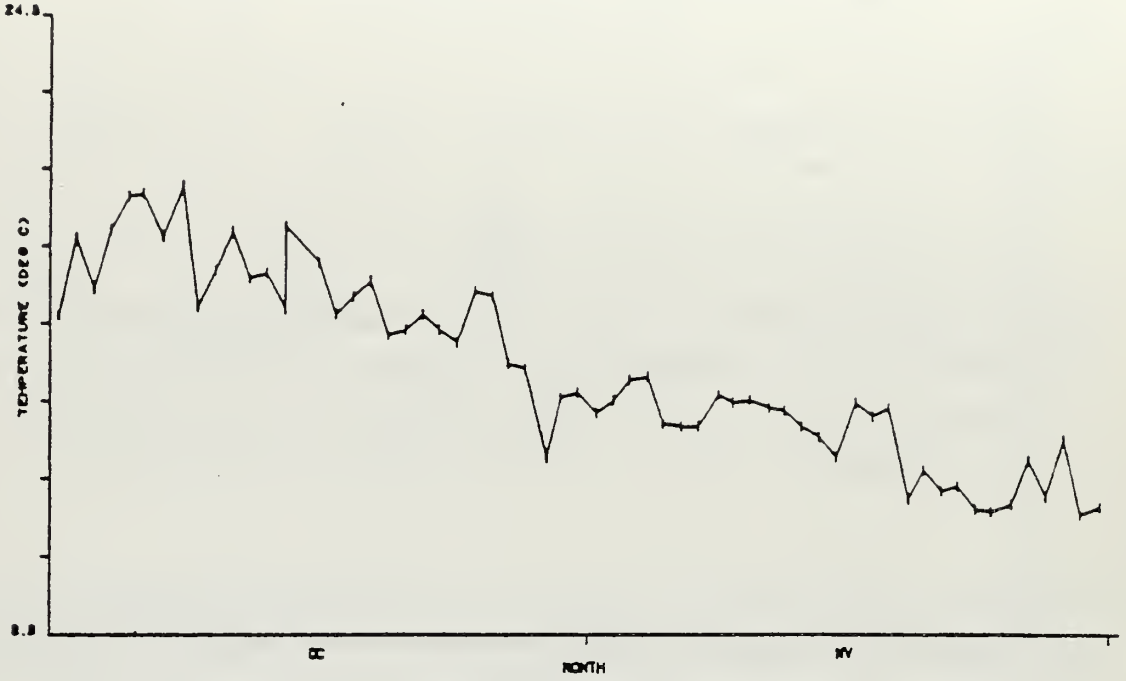

Figure 5-232

MET #3 PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

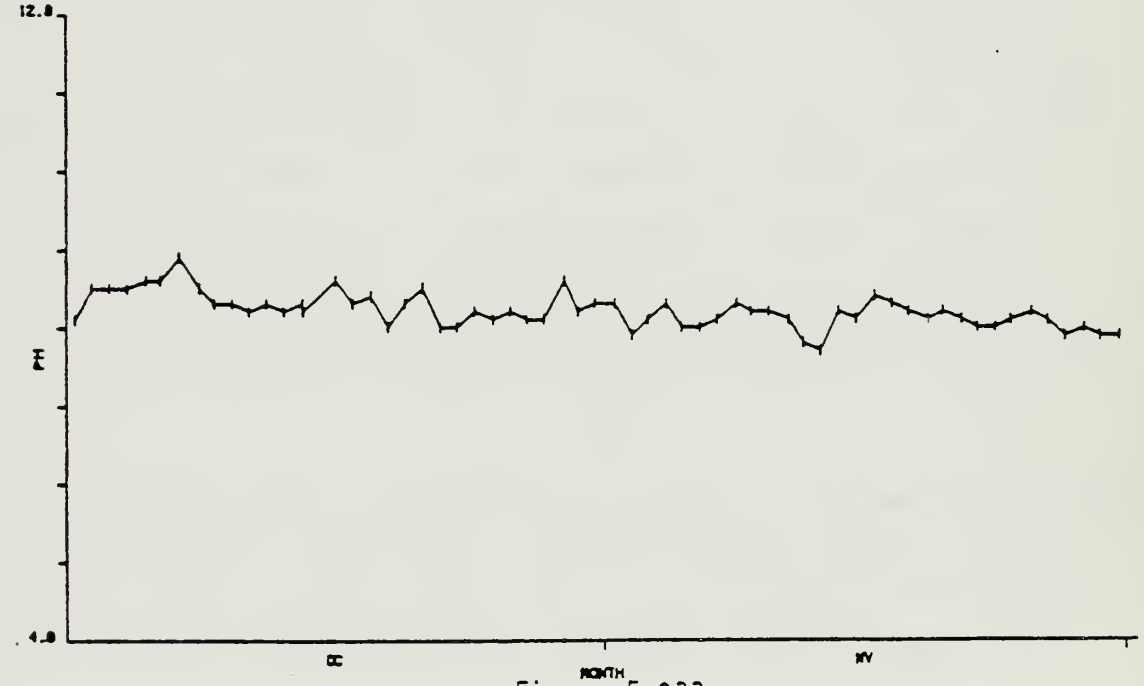

Figure 5-233

SEO FLUME HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

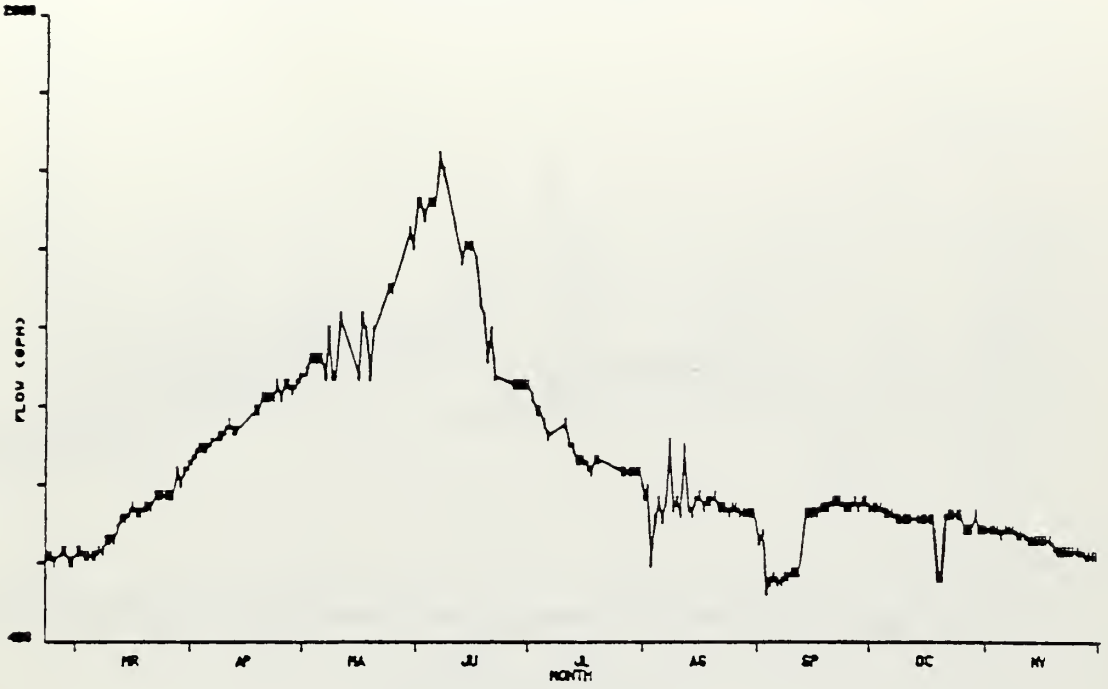

Figure 5-234

SEO FLUME CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

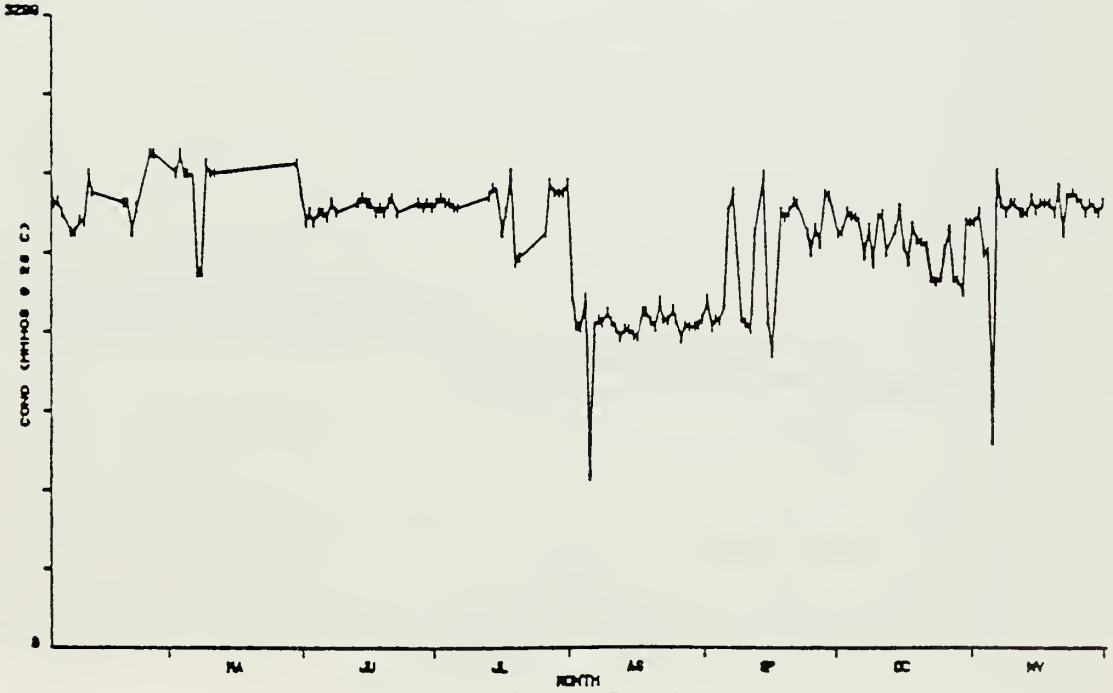

Figure 5-235

SEO FLUME TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

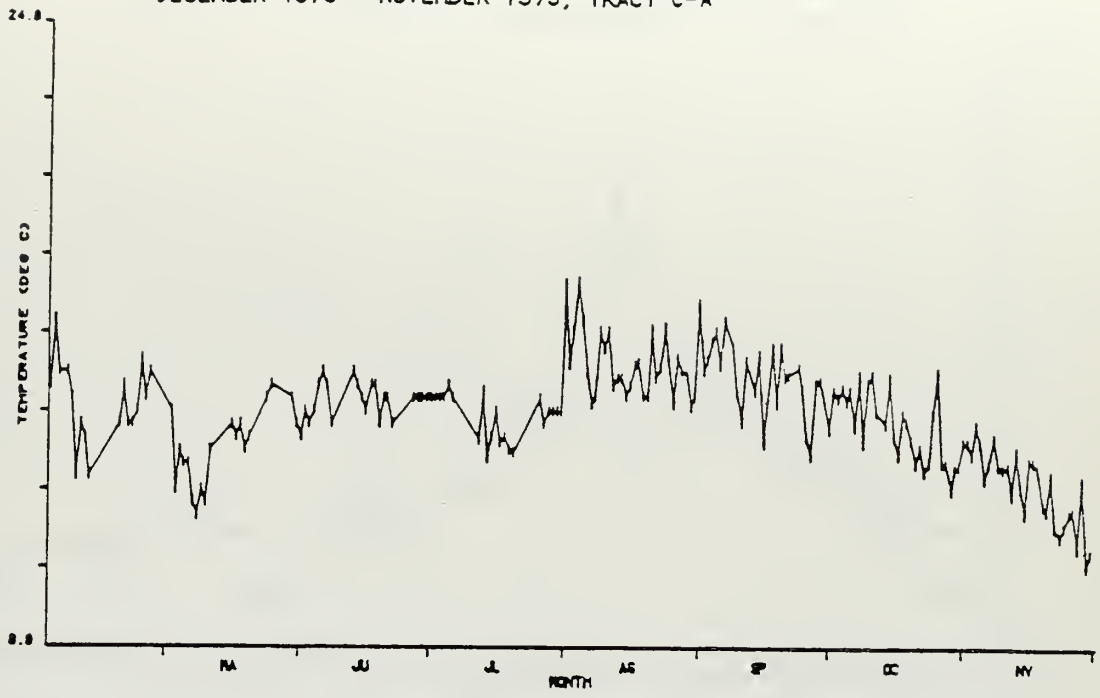

Figure 5-236

SEO FLUME PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

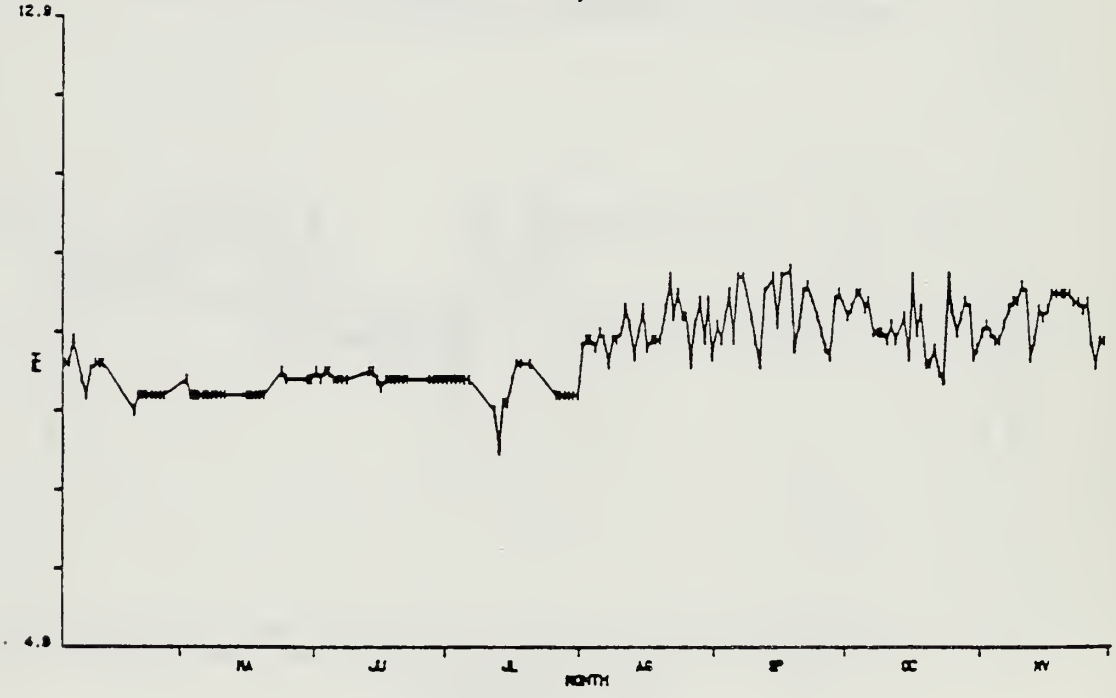

Figure 5-237

24 ROAD NORTH, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

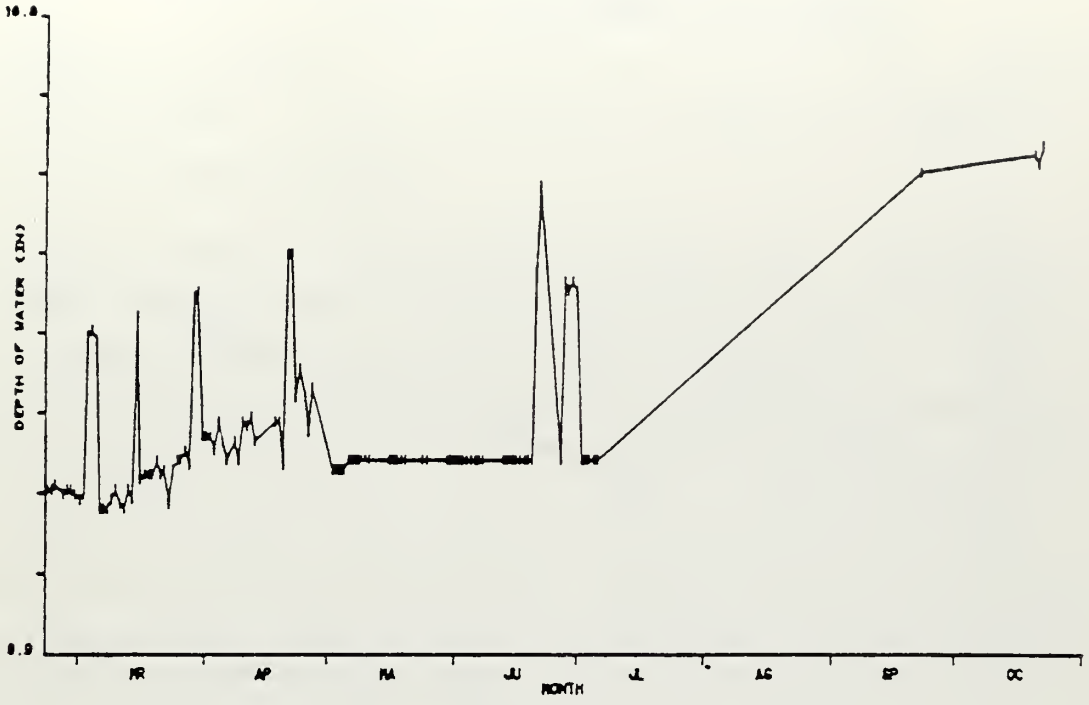

Figure 5-238

24 ROAD NORTH, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

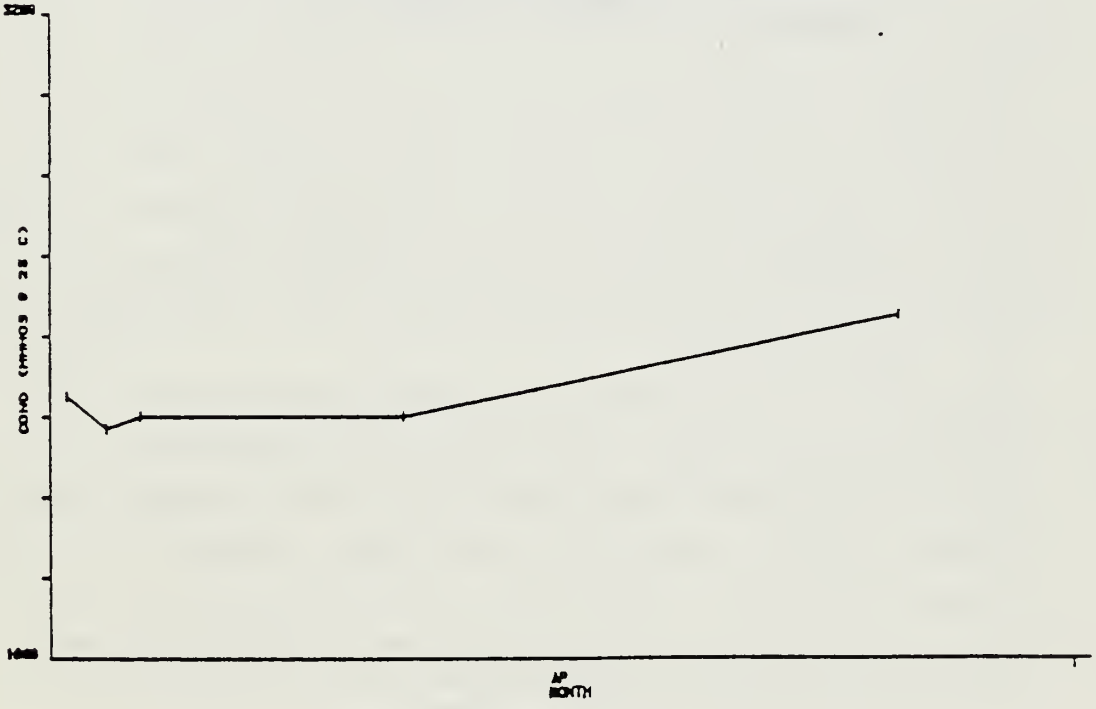

Figure 5-239

24 ROAD NORTH, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

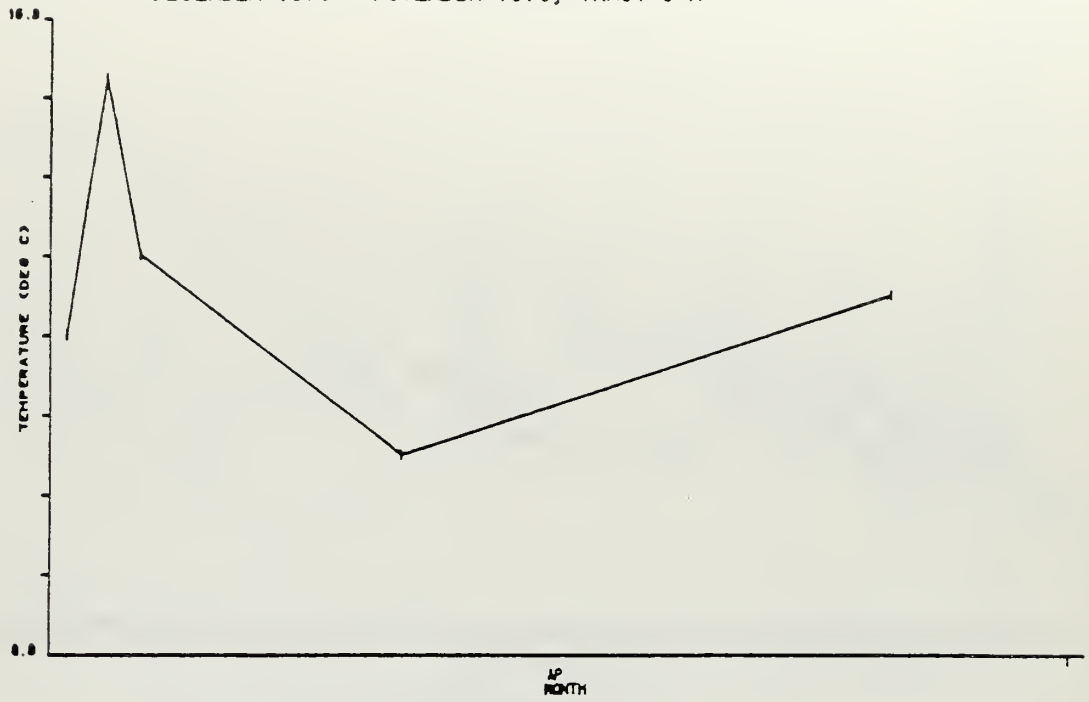

Figure 5-240

24 ROAD NORTH, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

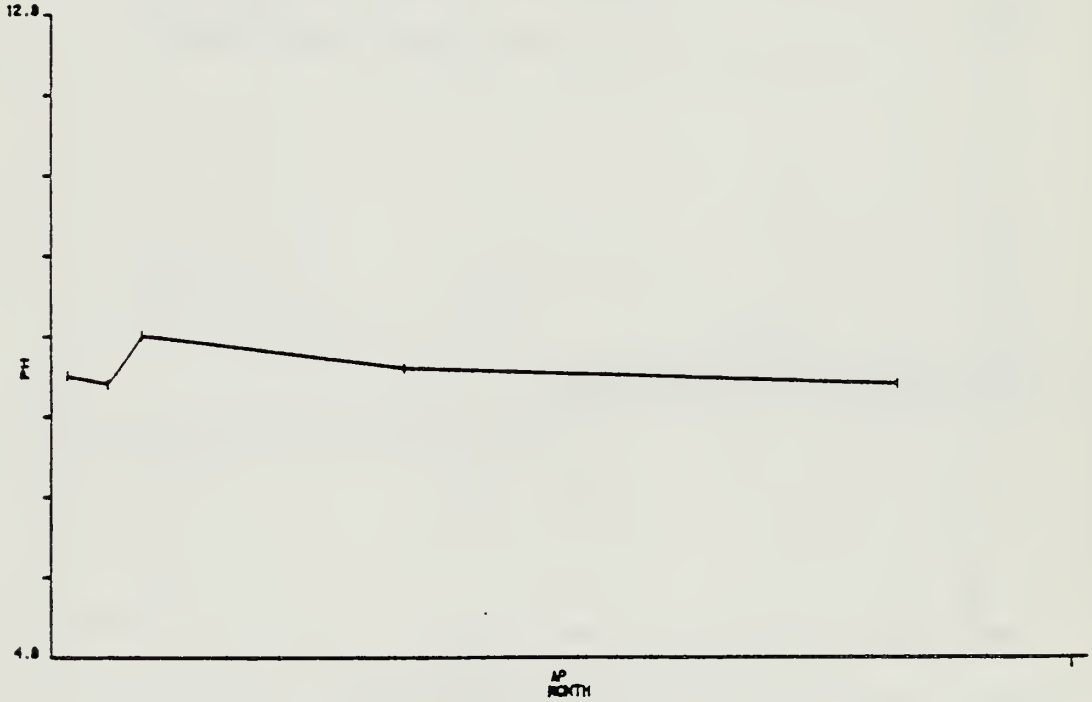

Figure 5-241

may have been due to alteration of the facility to allow for sumping of water from the Gulch by others. Plots of conductivity, temperature, and pH consist of only five data points each.

Plots of physical data for 24-Road Crossing South are shown in Figures 5-242 through 5-245. The hydrograph indicates a number of short-term fluctuations. There is an apparent rise in water level in March through May and a spike in late September and October which reflects effects from heavy rains during this period. Conductivities for this station show short-term large fluctuations, but no apparent significant long-term change. Temperature shows a normal seasonal fluctuation, except for the initial point on the plot in April which may have been a bad data point. The plot of pH indicates a jump in July and August from a level of about 8, with numerous short-term fluctuations after the first of August.

The physical data for the 24-Road Crest Stage hydrograph are shown on Figures 5-246 through 5-247. The hydrograph indicates numerous fluctuations in depth of water, but a relatively stable water level over the long-term, of between 4 and 6 inches in depth. The conductivity measurements at this station show large short-term fluctuations, but on the long-term, these fluctuations apparently center on a mean of about 2000 micromos. Temperature at this station shows some small short-term fluctuations, but a normal seasonal trend of increase in temperature from April through August. The plot of pH indicates that this parameter remains relatively constant at a value of slightly greater than 7 until the beginning of August, at which time it jumps to about 8.

The plot of the location of the "Leading Edge" is shown in Figure 5-250. The leading edge is defined as the distance downstream from 24-Road Crossing where the stream disappears. Under normal conditions, the lower portion of Corral Gulch down to the confluence of Yellow Creek is dry during much of the year. The leading edge was monitored to measure the impact of discharges

24 ROAD SOUTH, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

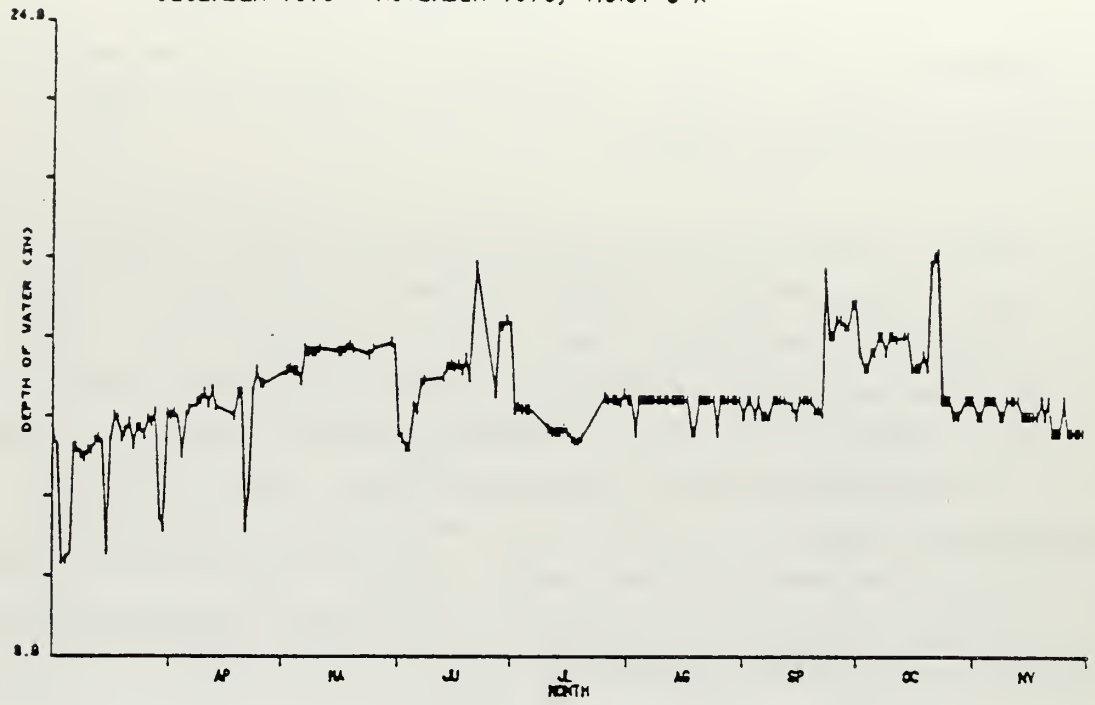

Figure 5-242

24 ROAD SOUTH, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

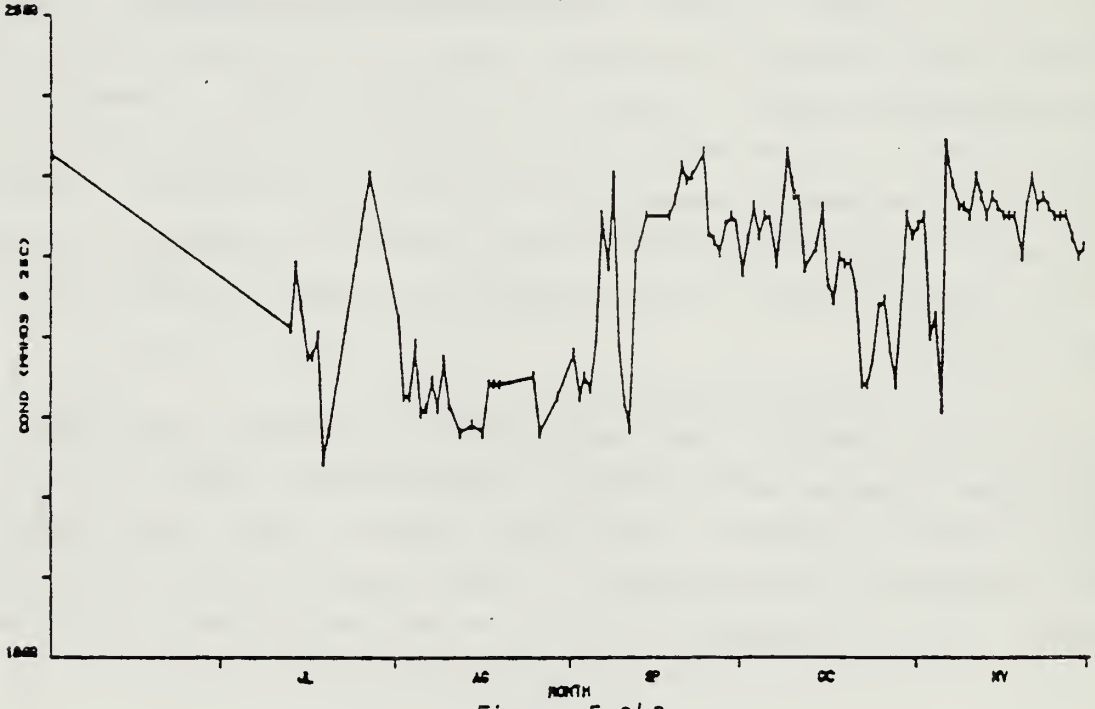

Figure 5-243

24 ROAD SOUTH, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

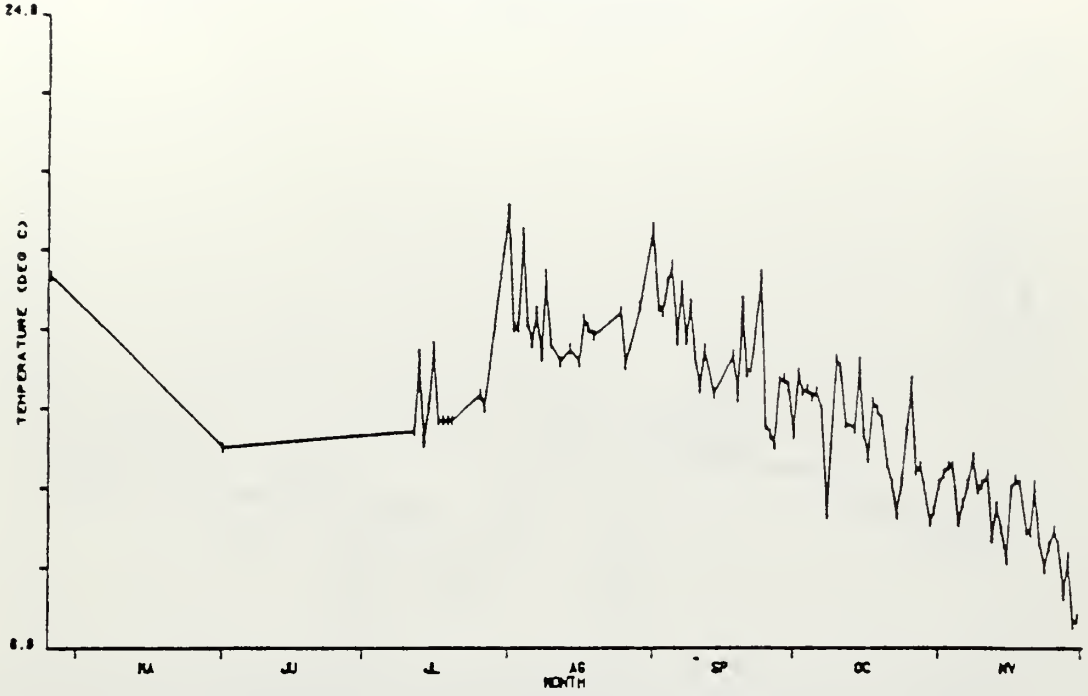

Figure 5-244

24 ROAD SOUTH, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

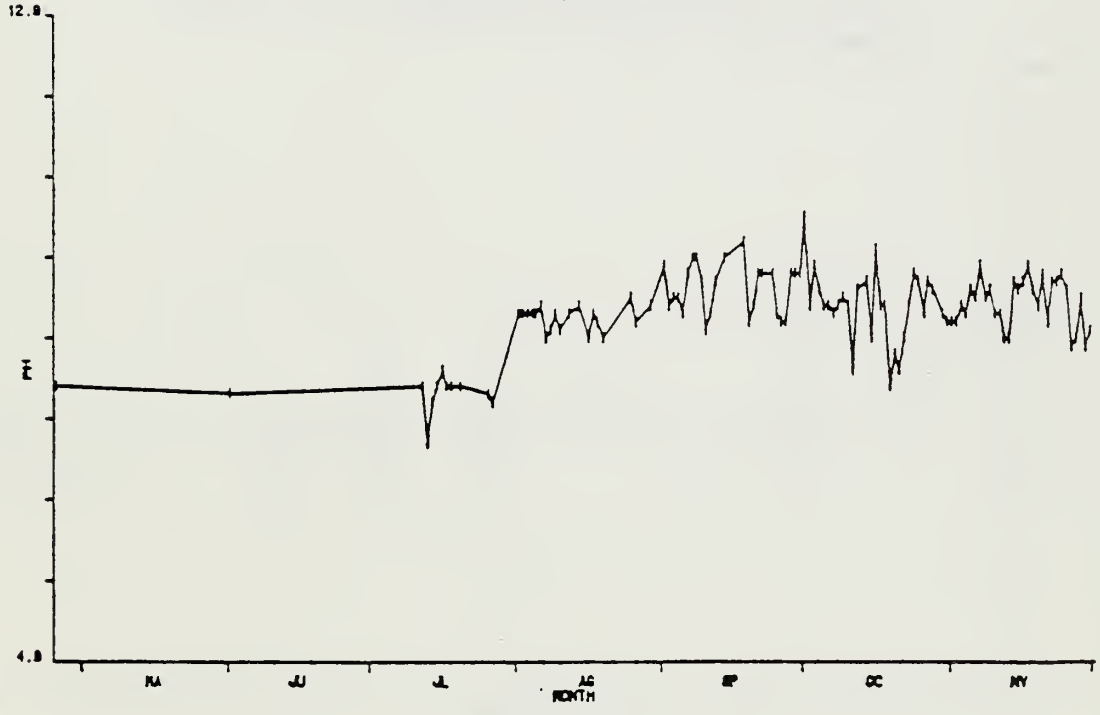

Figure 5-245

24 ROAD CREST STAGE, HYDROGRAPH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

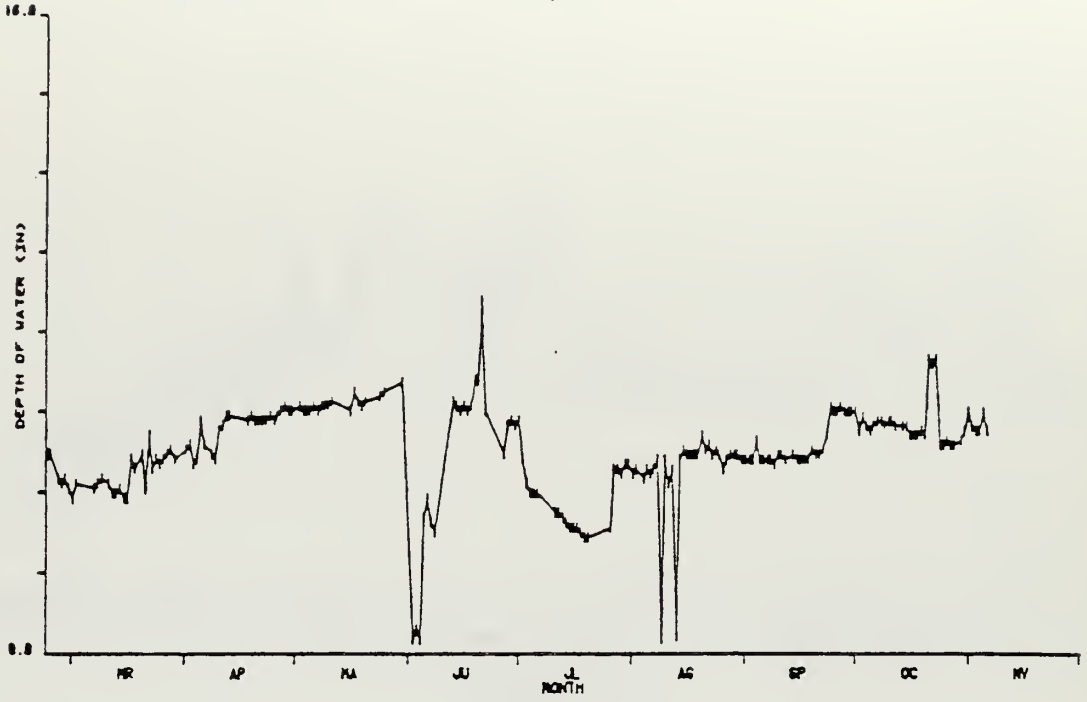

Figure 5-246

24 ROAD CREST STAGE, CONDUCTIVITY
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

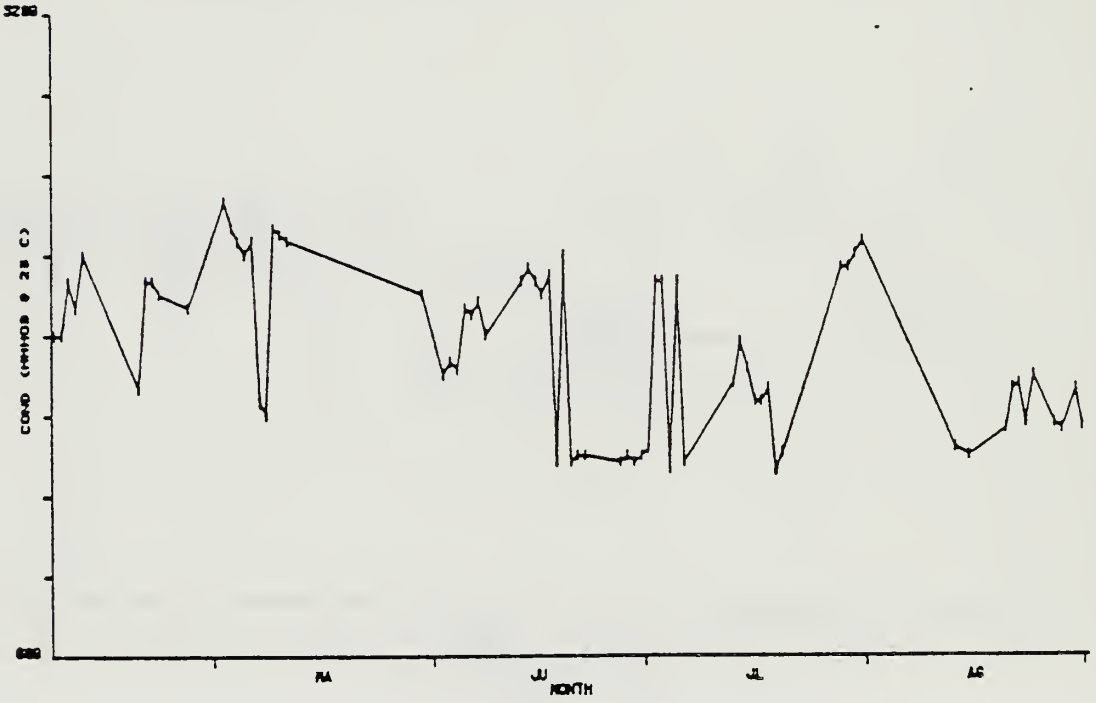

Figure 5-247

24 ROAD CREST STAGE, TEMPERATURE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

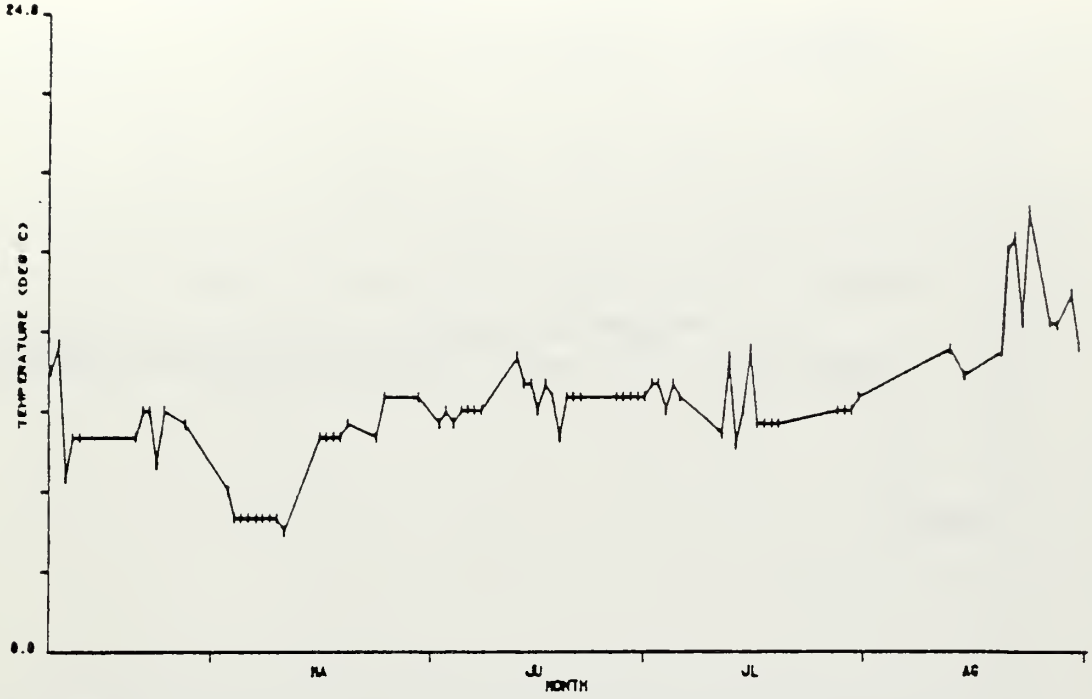

Figure 5-248

24 ROAD CREST STAGE, PH
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A

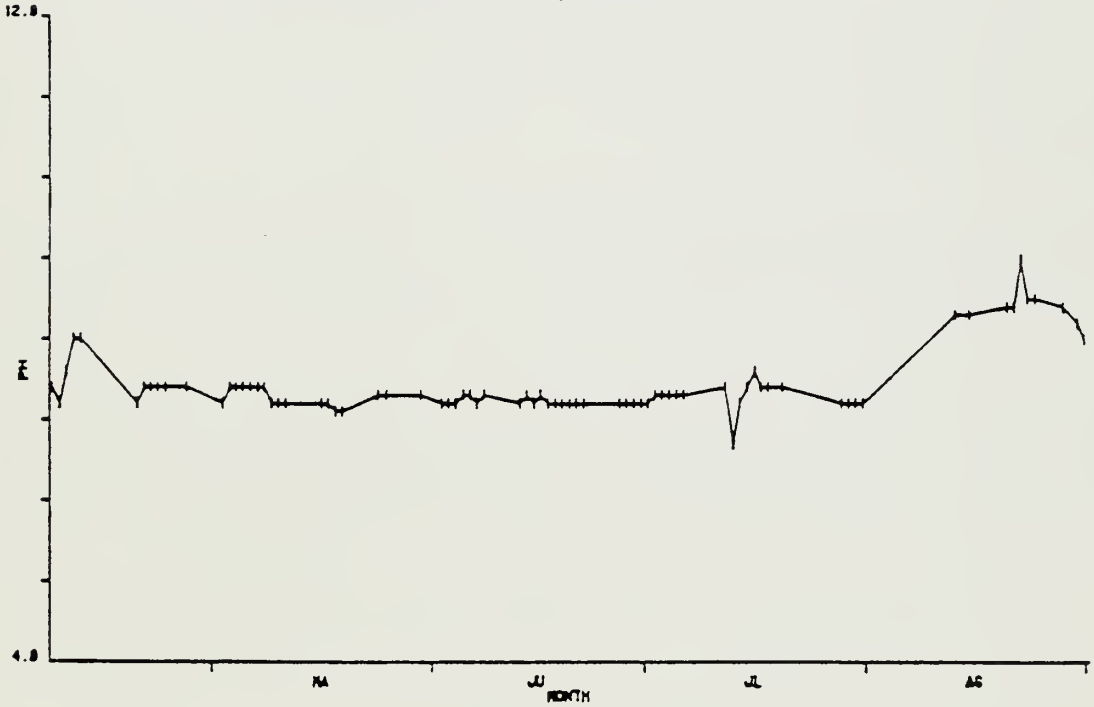

Figure 5-249

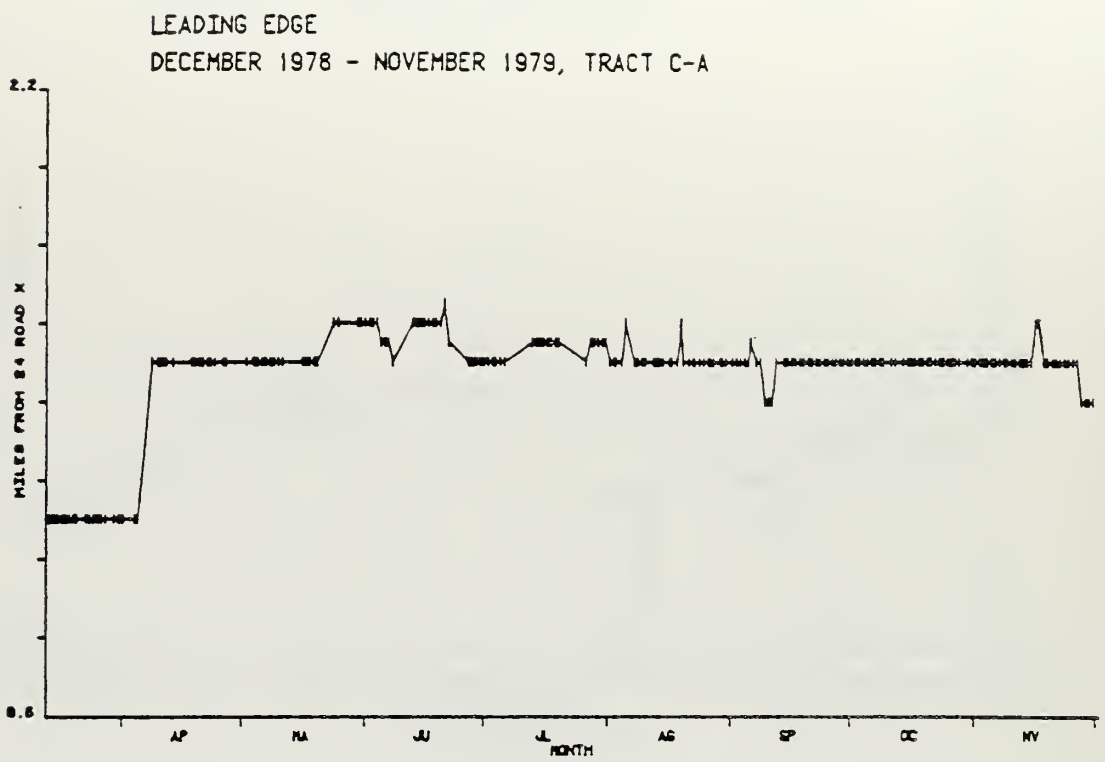
LEADING EDGE
DECEMBER 1978 - NOVEMBER 1979, TRACT C-A
2.2
0.6
MILES FROM S4 ROAD X
AP
MA
JU
JL
AG
SP
OC
NV
MONTH

Figure 5-250

on the hydrology of Corral Gulch. During March and the early part of April, the leading edge was located about 1.1 miles downstream from 24-Road Crossing. In early April the location of the leading edge moved further downstream, due primarily to increased runoff. For the remainder of the reporting period, the leading edge was located about 1.5 miles downstream of the 24-Road Crossing. There were minor fluctuations in this location, primarily due to increased runoff during late May and June.

5.4 SUMMARY

The hydrology program provides data necessary to satisfy lease stipulations and conditions of approval from the AOSO; assess impacts of dewatering and reinjection (development activities); provide input to engineering design of the mine and water handling system; supply information necessary for environmental disciplines to determine if mitigative measures are necessary; and collect data for compliance with permit stipulations. The hydrology program supplements baseline data which was initiated in 1977 and is used as a means of providing current data for comparison purposes. Stream gaging and erosion stations, springs and seeps, alluvial and deep aquifer holes, surface water impoundment, discharges, and reinjection and dewatering wells are monitored.

The results of the hydrology program are summarized below:

- Surface Water - Of the six gaging stations, two, Rinky Dink Gulch and Dry Fork, failed to show any flow during the reporting period. The natural flows for 1979 were similar to those for 1975 and 1978. The discharge of excess water affected the flows in Corral Gulch, but the discharge attenuated in Yellow Creek way above Yellow Creek gaging station. The leading edge was monitored during discharge periods.

  Examination of the water quality data collected at surface gaging stations during 1979 indicates that concentrations of many constituents were statistically different from baseline data.

- Springs and Seeps - Flow at all the springs was highly variable during the reporting period. Temperature conductivity and pH varied somewhat.

- Alluvial Groundwater - Many of the alluvial wells remained dry throughout the reporting period similar to baseline. Water levels in alluvial wells on Corral Gulch were influenced by discharge of dewatering water. For the wells where data were available, differences

between baseline and reporting period values of chemical concentration occurred for some parameters.

- Upper and Lower Aquifer Water - The cone of depression from dewatering the upper aquifer is elliplical with major axes to the north and northeast. Natural recharge occurs in the west and northwest portions of the tract. Reinjection is taking place in the northeast corner of the tract. The lower aquifer has not shown any response to dewatering; however, it shows a small response to reinjection in the northeast corner of the tract. Chemical data for deep aquifers taken during 1979 exhibit statistical differences from baseline data for several parameters.

- Development Activities - Flow data taken during the reporting period reflect discharges to Corral Gulch during the pump testing program. Likewise erosion data indicate that discharges to Corral Gulch resulted in minor changes of the stream channel profiles.

  Subsurface disposal permit data have been reported monthly since the onset of the testing program. These reports are available through the Colorado Department of Health and data are included in this report.

  Data taken in compliance with the NPDES permit were reported quarterly during 1978. These reports can similarly be obtained from the Colorado Department of Health and a summary is contained in the report.

SECTION 6

SPECIAL STUDIES

6.1 TOXICOLOGY

Samples of raw ore which were shipped to Naperville, Illinois have been examined and have been determined to be "representative" of MIS retorts. Arrangements are now being made with Union Oil Company Research Institute to conduct chemical characterization of these samples. Union's Research Institute was chosen because they conducted the testing of oil shale materials used in the American Petroleum Institute tests. Results of these tests will establish the need for future toxicology testing.

Concurrently, RBOSC has been cooperating with the Department of Energy (DOE) Oil Shale Task Force to carry out extensive toxicology testing with Tract C-a materials. Table 6-1 summarizes the testing program proposed by the task force. Collection of samples is scheduled for spring 1980, prior to the first retort burn. Sampling and testing will continue through and following burn of Retort 0.

Future plans call for chemical characterization and, if appropriate, toxicological testing of Lurgi spent shale ash. This will be carried out as soon as spent shale ash becomes available from Lurgi retorts in Germany, around mid-summer.

Table 6-1. Proposed Toxicology Testing Program for Tract C-a

	Chemical Characterization	In vitro				In vivo				
		Ames	Chromosomes	Mammal cells	Cytotocity	Inhalation	SCE	Prenatal	Acute	Skin Paint.
Liquids:										
Oil	X	X	X	X	X	?	X	?	X	X
Retort water	X	X	?	?	X		?	X	X	
Mine seepage water	X	X	?	?	X		?	X	X	
Dewatering water	X	X	?	?	X		?	X	X	
Scrubber blowdown	X	X	?	?	X		?	X	X	
Leachate	X	X	?	?	X		?	X	X	
Solids:										
Particulates	X	X	X	X	X	X	X	X	X	X
Scrubber sludge	X	X	?	?	?	?	?	?	?	?
Raw ore	X	?	?	?	?	?	?	?	?	?
Spent shale	X	?	?	?	?	?	?	?	?	?
Gases:										
Off gas	X	?	?	?	?	?	?	?	?	?

SCE = Sister Chromatid Exchange

6.2 Revegetation

1. Objectives

During RBOSC's commercial operations, processed shale will be produced as a by-product of surface retorting. This material will require surface disposal because all of the processed shale cannot be returned by slurry to the in-situ retorts. RBOSC initiated the 1976 revegetation experiments to determine a feasible method to reestablish productive, self-sustaining wildlife habitat on processed shale disposal sites.

2. Methods

The 1976 experimental revegetation plot (R3) was established September 29-November 8, 1976, and is located near the southeast corner of Tract C-a, T2S, R99W, Section 10. The plot is situated in an area with a southeast aspect and slope of approximately 20 percent (see Environmental Monitoring Sites Map 2 - Ecological, in map pocket).

The plot was designed to simulate an artificial soil profile for use in overburden/processed shale disposal piles. This profile, when placed on top of the processed shale, is expected to inhibit capillary migration of toxic elements into the surface plant growth medium. The 1976 experiments were designed to investigate the effectiveness of the proposed artificial soil profile. The experimental treatments include soil types, mulch types, seeding intensity, and shrub establishment methods.

The following strata simulate the proposed artificial soil profile.

0.15m (0.5 ft) topsoil
0.30m (1 ft) subsoil
0.90m (3 ft) segregated mine run (12 x 0 in size)
0.52m (1.75 ft) compacted Tosco II processed shale

The soil profile was prepared by separately stockpiling topsoil (0.15 m), subsoil (0.3 m), and excavated sandstone (0.3 m). Mine run material was then obtained by excavating 0.9 m of rock material from the revegetation site and stockpiling it. A plastic sheet was laid into the 1.7 m deep trench to insure that no contamination of ground water would occur, and to facilitate collection of any leachate for analysis. Due to the limited availability of Tosco II processed shale, approximately .51 m of processed shale was placed on top of the plastic sheet. The processed shale was compacted to prevent penetration and leaching by water, and to simulate compacted processed shale proposed for the ultimate commercial disposal pile configuration. Measurements of the processed shale density and depth at the 1976 experimental plot are presented in RBOSP Progress Report 9. The control plot was underlain by approximately 0.51 m of sandstone, which had been previously excavated from the revegetation site and stockpiled. Following compaction of the processed shale, 0.9 m of segregated mine run overburden (0.3 x 0 m size) was bulldozed over the processed shale and the excavated sandstone of the control plot. Estimates of the percent fines occurring in the artificial soil profile are presented in RBOSP Progress Report 9. This 0.9 m-layer of mine run overburden represents a combination of the large and crushed rock layers as outlined in the RBOSP Detailed Development Plan. The topsoil and subsoil were replaced in proper sequence. The edges of the simulated artificial soil profile were graded to improve the aesthetic appearance of the revegetation plots.

Diversion ditches were constructed along the upper edge of the artificial soil profile to reduce erosion. The 1976 revegetation site utilizes a 53 x 53 m area (0.3 ha or 0.70 ac) (Figure 6-1). An approximate 23 m wide boundary area surrounding the revegetation site was disturbed by operation of machinery, and removal and temporary stockpiling of soil material. Thus a total of 1.0 ha (2.41 ac) was disturbed by the 1976 experiments.

Each 6 x 6 m plot received one treatment and the six treatments were replicated six times for a total of 36 plots (Figure 6-1). Each plot is surrounded by a 1 m buffer zone. A 5 - 6 m buffer zone was provided along the outermost perimeter of the treatment plots to reduce microclimatic effects, and a 3 m buffer zone was placed in the center of the plot at the interface of the

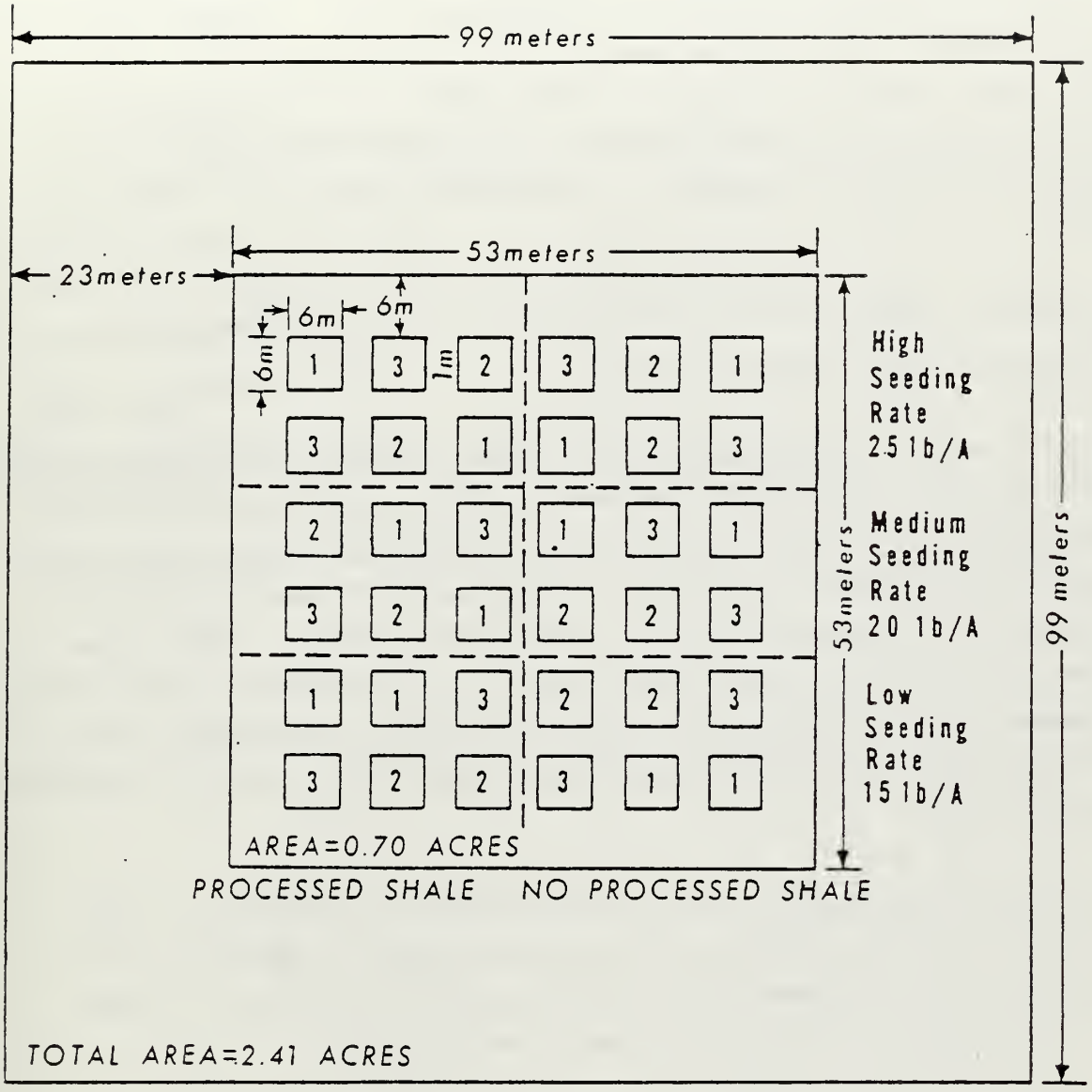

Figure 6-1.
Generalized plot layout for revegetation plot R3 on oil shale tract C-a Rio Blanco County, Colorado (initiated in 1976)

processed shale and control area. Microclimatic effects are expected to be more severe at the perimeter of the simulated profile and thus a larger buffer zone has been provided at the perimeter than between plots. Treatments were allocated randomly in each of three complete blocks located adjacent to each of the plots. Within each 6 x 6 m treatment plot, three 1 x 1 m subplots were randomly established and permanently marked for subsequent data collection. The factorial ANOVA used for analysis of revegetation data is illustrated on Table 6-2.

The test site was fenced with four-strand barbed wire to discourage large grazers, primarily feral horses and cattle.

Grasses, forbs, and shrubs were seeded as a composite mixture after the artificial soil profile had been prepared and the seedbed graded. Seed was drilled into the ground using a conventional grassland drill equipped with depth bands and a single-seed box and agitator. Rice hulls were added to the seed mixture as a "filler substance" to increase the bulk of seed in the seed box. Depth bands insured that seed was not drilled deeper than 2 cm. It is expected that drilling will be necessary for the large scale operation of seeding the disposal piles, therefore the present studies were designed to simulate the large scale operation as much as possible.

Seed was drilled in 60 m-long strips along the contours of the slope. Since the drill has a 2.5 m drilling span, two passes were made to seed the 6 x 6 m plots, leaving a narrow unseeded band along the edge of each plot. Drilling resulted in a spacing of 12 to 18 cm between planting rows.

A composite mixture of grasses, forbs, and woody plants (Table 6-3) was sown in preference to pure species stands. This mixture consists of both introduced and native species. Nearly all the species (Table 6-3) have demonstrated success in earlier species adaptability trials when sown in pure stands in the sagebrush and pinyon-juniper ecosystems (Cook et al. 1974; Sims and Redente 1974). With several exceptions, the preliminary results of the 1975 RBOSP revegetation plots indicate that these species are successful when sown in a composite mixture on Tract C-a.

Table 6-2. Analysis of Variance for a Mixed Model Factorial Design Used on Experiment Revegetation Plot R3

Source of Variation		Degrees of Freedom	F-Ratio
1.	Soil type a=2	a-1= 1	1/8
2.	Seeding level b=3	b-1= 1	2/8
3.	Mulch c=3	c-1= 3	3/8
4.	Seeding level x Soil type	(a-1)(b-1)= 2	4/8
5.	Mulch x Soil type	(a-1)(c-1)= 2	5/8
6.	Mulch x Seeding level	(b-1)(c-1)= 4	6/8
7.	Mulch x Seeding level x Soil type	(a-1)(b-1)(c-1)= 4	7/8
8.	Error (n=6)	abc(n-1)= 90	
9.	Total	abcn-1=107	

Table 6-3. Plant Species Suitability and Projecting Sowing Rates (lb/acre) of Viable Seed for Species utilized in the Experimental Revegetation Plot R3 initiated in 1976 on Oil Shale Tract C-a, Rio Blanco County, Colorado

Species	Suitability Rating	Seeding Rates (lbs/acre)
Grasses		
Luna pubescent wheatgrass (Agropyron trichophorum var. Luna)	2,4,6,8,9	2.0
Rosana western wheatgrass (Agropyron smithii var. Rosana)	4,5,8,9	2.0
Sodar streambank wheatgrass (Agropyron riparium var. Sodar)	3,5,8,9	1.5
Indian ricegrass (Oryzopsis hymenoides)	2,4,5,7,9	1.0
Manchar brome (Bromus inermis)	1,6,8	1.5
Green needlegrass (Stipa viridula)	2,5,7	1.5
Subtotal		9.5
Forbs		
Lewis flax (Linum lewisii)	2,5	1.00
Lutana cicer milkvetch (Astragalus cicer var. Lutana)	6,11	0.75
Utah sweetvetch (Hedysarum utahensis)	2,5	0.50
Madrid yellow sweetclover (Melilotus officinalis var. Madrid)	2,4,5,9,11	0.75
Rocky Mountain Penstemon (Penstemon strictus var. Bandera)	3,5,9	0.50
Common daisy (Chrysanthemum leucanthemum)	3,5,9	0.50
Subtotal		4.00

Table 6-3. (Continued)

Species	Suitability Rating	Seeding Rates (lbs/acre)
Shrubs		
Bitterbrush (Purshia tridentata)	1,5,9,10,11	1.5
Mountain mahogany (Cercocarpus montanus)	1,5,10	1.5
Fourwing saltbush (Atriplex canescens)	1(seeds),3,4,5,9	1.25
Winterfat (Ceratoides lanata)	1,5,10	.75
Rubber rabbitbrush (Chrysothamnus nauseosus)	3,5,9,10,11	.75
Serviceberry (Amelanchier alnifolia)	2,5,10,11	.75
Subtotal		6.5
Trees		
Pinyon pine (Pinus edulis)	3,5,9,11	.4
Subtotal		.4
TOTAL		20.4

Suitability ratings, underlining indicates species observed on site as part of the environmental baseline studies:

1 highly palatable
2 moderately palatable
3 unpalatable
4 soil stabilizer
5 native to Colorado
6 introduced species
7 bunch grass
8 sod grass
9 drought resistant
10 browse
11 cover for game

While it would be advisable to use local seed sources (NAS 1974), they are generally not available at present. For the present studies, it was necessary to obtain seed from a number of private companies and governmental agencies throughout the arid west.

For the 1976 test, three seeding rates were used (Figure 6-1). The total pure live seed (PLS) per acre was 15 lb, 20 lb, and 25 lb respectively, for the low, medium and high rates. Containerized seedlings were also planted, and their success was compared to seeded individuals of the same species. With the exception of Pinus edulis and Sphaeralcea coccinea, the thirteen species of containerized seedlings were shrubs. These included Atriplex bonnevillensis, A. canescens, A. gardneri, Artemisia tridentata, Camphorosma monospheliaca, Cercocarpus montanus, Chrysothamnus nauseosus, Ceratoides (Eurotia) lanata, Kochia prostrata, Purshia tridentata, and Rhus trilobata.

3. Results and Discussion

Data collected prior to the 1979 sample period were reported in the Revegetation Program 1976, 1977, and 1978 Annual Reports. Data reported herein pertains to cover estimates and biomass determinations made during 1979.

a. Percent Cover Data - Cover data taken for Site R3 during 1979 are summarized on Table 6-4, and the complete data set is presented in Appendix 6-2.1. Statistical analyses are included in Appendices 6-2.2, 6-2.3, and 6-2.4.

Coverage (including all species) at Site R3 was 51.6 percent. This represents an increase from the 45 percent total coverage present prior to disturbance (RBOSC 1978). The dominant species included wheatgrass species (Agropyron spp.), Indian ricegrass (Oryzopsis hymenoides), cicer milkvetch (Astragalus cicer), winterfat (Ceratoides lanata), and four-winged saltbush (Atriplex canescens). Respective coverages for these species were 24.4, 2.5, 3.0, 8.6 and 5.9 percent (Table 6-4).

Table 6-4. Average Percent Cover of Plant Species Present on RBOSC Revegetation Plot R3 During Fall of 1977, 1978, and 1979, Tract C-a

	1977	1978	1979
Grasses			
Agropyron spp	2.4	7.1	17.1
Agropyron trichophorum	1.4	2.5	7.3
Bromus inermis	1.2	3.4	1.4
Bromus tectorum	0.7	0.1	0.4
Oryzopsis hymenoides	0.4	2.7	2.5
Stipa viridula	0.2	0.3	.5
Others	<0.1	0.4	1.1
Total Grasses	6.4(32)[1/]	14.5(53)[1/]	30.3(59)[1/]
Forbs			
Melilotus officinalis	6.5	3.9	0.3
Salsola kali	0.9	0.4	0.8
Astragalus cicer	0.8	0.7	3.0
Physaria floribunda	0.3	0.1	0.1
Hedysarum utahensis	0.1	<0.1	---
Penstemon strictus	0.1	0.1	---
Linum lewisii	0.1	0.2	0.2
Chrysanthemum leucanthemum	<0.1	---	---
Others	0.3	0.2	0.1
Total Forbs	9.2(45)[1/]	5.7(21)[1/]	4.4(9)[1/]
Shrubs			
Ceratoides (Eurotia) lanata	2.3	3.8	8.6
Atriplex canescens	1.2	2.4	5.9
Cercocarpus montanus	0.7	0.1	---
Purshia tridentata	0.4	0.3	0.3
Chrysothamnus spp	<0.1	0.1	0.6
Artemisia tridentata	---	0.1	0.2
Atriplex gardneri	---	<0.1	<0.1
Atriplex bonnevillensis	---	0.1	0.5
Kochia prostrata	---	0.2	0.7
Camphorosma monospeliaca	---	0.1	<0.1
Total Shrubs	4.7(23)[1/]	7.3(26)[1/]	16.9(33)[1/]
TOTAL	20.3	28.0	51.6
Planted Species	18	28	19
Invaded Species	2	1	8
Total	20	29	27

[1/] Number in parentheses is the percent represented by grasses, forbs, or shrubs

Average coverage for grass species was 30.3 percent. When compared to 14.5 percent grass coverage for 1978, this represents a significant increase ($\alpha = 0.05$) (Table 6-5). Agropyron cristatum, Agropyron spp., A. trichophorum, and Stipa viridula (green needlegrass) registered significant increases in coverage ($\alpha = 0.05$). Smooth brome (Bromus inermis) had a significant decrease in coverage whereas the differences noted for Indian ricegrass were not significant ($\alpha = 0.05$) (Table 6-5). Some of the increase noted between years may be the result of sampling inconsistency. Different investigators estimated coverage in 1978 and 1979.

Average forb coverage was not significantly different between years; respective values for 1978 and 1979 were 5.7 and 4.4 percent (Tables 6-4, 6-5). However, yellow sweetclover (Melilotus officinalis) experienced a significant decrease, and cicer milkvetch registered a significant increase in coverage. Russian thistle (Salsola kali), an undesireable invader, increased from 0.4 in 1978 to 0.8 percent in 1979. Forbs accounted for only 9 percent of total vegetational coverage in 1979. This percentage represents a decrease from 45 and 21 percent for 1977 and 1978 respectively (Table 6-4).

Coverage of shrubs averaged 16.9 percent in 1979. This accounts for 33 percent of total coverage, and is a significant increase from 1978 shrub coverage ($\alpha = 0.05$) (Tables 6-4, 6-5). Winterfat, four-winged saltbush, and burningbush (Kochia prostrata) had significant increases between years. These species were planted as tubelings during June 1977, but Ceratoids and Atriplex were seeded as well. Individuals planted as tubelings appeared to be doing very well at Site R3, and much of the increased shrub coverage may be attributable to these individuals.

Species richness for 1979 was 27, which was a decrease from the 29 species encountered during 1978. The number of planted species encountered decreased while invaders increased (Table 6-4). Although eight invading species were encountered, these species represent a minor portion of total coverage. Respective coverages of invading grasses, forbs, and shrubs were 1.5, <0.9, and < 0.6 percent (Table 6-4, Appendix 6-2.1).

Table 6-5. Summary of Statistical Comparisons Between 1978 and 1979 Coverage on RBOSC Revegetation Study Site R3, Tract C-a[1/]

Species	F	PR>F[2/]
Grasses		
Agropyron cristatum	6.30*	0.0023
Agropyron spp.	4.48*	0.0001
Agropyron trichophorum	8.68*	0.0001
Bromus inermis	2.24*	0.0001
Bromus tectorum	7.65	0.1246
Oryzopsis hymenoides	1.01	0.9502
Stipa viridula	6.78*	0.0001
Total Grasses	2.14*	0.0001
Forbs		
Melilotus officinalis	329.34*	0.0001
Salsola kali	1.10	0.7965
Astragalus cicer	22.50*	0.0001
Linum lewisii	1.69	0.1762
Unknown forb	2.60	0.2225
Cryptantha sericea	2.40	0.2261
Total Forbs	1.02	0.9345
Shrubs		
Ceratoides lanata	7.81*	0.0001
Atriplex canescens	9.88*	0.0001
Purshia tridentata	1.08	0.7307
Artemisia tridentata	8.67	0.2165
Atriplex gardneri	1.85	1.0000
Atriplex bonnevillensis	67.88*	0.0292
Kochia prostrata	28.90*	0.0014
Camphorosma monospeliaca	1.02	1.0000
Total Shrubs	7.52*	0.0001
Total Species	4.30*	0.0001

[1/] Complete analyses are presented in Appendix 6-2.2

[2/] PR>F represents the significance probability (α) associated with F

* ($\alpha = 0.05$)

Summary ANOVA results comparing coverage on various treatments used at Site R3 is presented on Table 6-6. When all grasses, forbs, and shrubs were considered, no significant differences in cover were noted for the substrate or the mulch treatments. Significant differences ($\alpha = 0.01$) were measured between seeding treatments for grasses, forbs, and shrubs of both planted and invaded species. Differences between seeding treatments also were noted in 1978 and 1977 (RBOSC 1979). The 1978 differences ($\alpha = 0.07$) were not as definitive as those for 1977 and 1979 ($\alpha = 0.01$ for both years).

When individual species were considered, seeding intensity was the most prominent source of the significant differences noted. Eight species exhibited significant differences ($\alpha = 0.05$) based on seeding rate, three species on substrate, and two species for the mulch treatment (Appendix 6-2.4). Wheatgrass species, Indian ricegrass, cheat-grass (Bromus tectorum), cicer milkvetch, Russian thistle, winterfat, and four-winged saltbush had significant differences relative to seeding intensity. All of these species except Russian thistle and cheat-grass are important contributors to total coverage at Site R3 (Table 6-4). Only smooth brome and winterfat were significantly affected by mulch, whereas crested wheatgrass (Agropyron cristatum, smooth brome, and Indian ricegrass exhibited significant differences based on substrate ($\alpha = 0.05$). These significant differences apparently were masked by the lack of differences for species of similar growth form and, consequently, were not evident when species were segregated by growth form.

A number of the interactive effects were shown to be significant (Table 6-6). These included substrate x seeding for planted shrubs, substrate x mulch for both invaded grasses and all invaders, and substrate x seeding x mulch for planted grasses, invading grasses, and all invaders. Significant differences for these interactions are influenced in part by the high degree of significance exhibited for the seeding treatment alone ($\alpha = 0.01$). It is unclear why there were significant differences for invading species when none of this individual invading species showed significant differences for mulch treatments, and only crested wheatgrass exhibited a significant difference for substrate (Appendix 6-2.4).

Table 6-6. Summary of Analysis of Variance Results for 1979 Cover Estimates at RBOSC Revegetation Study Site R3[1/]

Source of Variation	Total		Planted Species		Planted Grasses		Planted Forbs		Planted Shrubs		Invaded Species		Invaded Grasses		Invaded Forbs	
	F	PR>F[2/]	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F
Substrate	0.96	0.3288	0.27	0.6041	0.28	0.5952	0.82	0.3675	0.35	0.5534	2.85	0.0948	1.70	0.1959	1.42	0.2360
Seeding	13.77*	0.0001	20.27*	0.0001	23.61*	0.0001	6.68*	0.0020	8.57*	0.0004	17.37*	0.0001	10.73*	0.0001	8.04*	0.0006
Mulch	2.45	0.0920	1.58	0.2112	2.34	0.1018	2.81	0.0657	0.65	0.5235	2.72	0.0715	4.32*	0.0162	0.16	0.8502
Substrate x Seeding	0.27	0.7645	0.51	0.6032	2.44	0.0926	1.38	0.2556	3.43*	0.0367	0.85	0.4325	0.79	0.4548	0.17	0.8428
Substrate x Mulch	0.43	0.6550	0.15	0.8582	1.65	0.1978	0.45	0.6420	1.18	0.3118	5.49*	0.0056	4.17*	0.0185	1.75	0.1791
Seeding x Mulch	0.28	0.8892	0.09	0.9844	0.60	0.6670	0.58	0.6768	0.53	0.7115	1.00	0.4104	2.05	0.0944	0.41	0.7989
Substrate x Seeding x Mulch	1.35	0.2587	1.80	0.1351	4.59*	0.0020	0.53	0.7161	0.51	0.7300	4.54*	0.0022	4.42*	0.0026	0.74	0.5684

[1/] Complete analyses are presented in Appendix 6-2.2

[2/] PR>F represents the significance probability (α) associated with F

* (α = 0.05)

b. Biomass Data - Above-ground biomass at R3 totaled 2151 kg/ha during 1979. Grasses accounted for 838, forbs 55, and shrubs 1258 kg/ha (Table 6-7). Wheatgrass species were the dominant grasses totaling 722 kg/ha. Cicer milkvetch and Russian thistle were the important forbs, however, their total biomass was only 48 kg/ha. Total shrub biomass was 1258 kg/ha, with winterfat and four-winged saltbush being the dominant species.

Total biomass at R3 was noticeably greater than that recorded at Sites R1 and R2 during 1978. Respective totals for these sites were 1126 and 962 kg/ha (RBOSC 1979). Productivity recorded in the upland sagebrush vegetation type during baseline studies was considerably lower than that recorded at any of the revegetation study sites after three years of growth. Grasses and forbs totaled 304 kg/ha during the baseline period. In addition, herbaceous production recorded from 1977 through 1979 on range study transects (see Section 3.1c) was lower than the aforementioned baseline study. Based on herbaceous species, these data indicate revegetation efforts at R3 have resulted in production that exceeds that occurring in the natural plant communities of the area.

Differences in shrub production between Sites R1, R2 and R3 result from the planted shrub tubelings at R3. Tubelings afford these individuals a competitive advantage over seeded species, and this results in more rapid growth. Furthermore, as shrubs increase in size, woody stems become important factors contributing to above-ground biomass. The volume of material available for browse may be considerably less than total biomass values reported herein.

Analysis of variance data (Table 6-8) indicate that there are no significant differences in total biomass during 1979 for primary or interactive effects considered. Nevertheless, as reported for coverage estimates at R3, biomass determinations also indicate that seeding intensity may be of importance. Planted forbs, and all categories of invading species exhibited significant differences ($\alpha = 0.05$) in biomass for the seeding treatment (Table 6-8). Biomass of invading species increases as seeding rate decreases. For example, average biomass of invading grasses was 3.0 for high, 16.0 for medium, and 36.0 kg/ha for low seeding rates (Appendix 6-2.5). These data support the recommendation that seeding rates used for revegetation efforts be 20 lb/A or greater (RBOSC 1979).

Table 6-7. Average Above-ground Biomass (kg/ha) of Plant Species Sampled During 1979 on RBOSC Revegetation Study Site R3, Tract C-a[1/]

Species	Above-Ground Biomass (kg/ha)		
Grasses			
Agropyron spp	523		
Agropyron trichophorum	199		
Bromus inermis	29		
Bromus tectorum	6		
Oryzopsis hymenoides	43		
Stipa viridula	12		
Others	26		
Total Grasses	838(40)[2/]	Grasses Invaded	33
		Grasses Planted	805
Forbs			
Melilotus officinalis	1		
Salsola kali	16		
Astragalus cicer	32		
Physaria floribunda	0.1		
Linum lewisii	3		
Others	3		
Total Forbs	55(3)[2/]	Forbs Invaded	20
		Forbs Planted	35
Shrubs			
Eurotia lanata	588		
Atriplex canescens	496		
Cercocarpus montanus	0.1		
Purshia tridentata	7		
Chrysothamnus spp	32		
Artemisia tridentata	25		
Atriplex gardneri	1		
Atriplex bonnevillensis	47		
Kochia prostrata	59		
Camphorosma monospeliaca	3		
Total Shrubs	1258(58)[2/]	Shrubs invaded	1
		Shrubs planted	1257
TOTAL	2151		

[1/] Complete biomass data are presented in Appendix 6-2.5

[2/] Number in parentheses is the percentage biomass accounted for by the respective growth form

Table 6-8. Summary of Analysis of Variance Results for 1979 Biomass Determinations at RBOSC Revegetation Study Site R3[1/]

Source of Variation	Total		Planted Species		Planted Grasses		Planted Forbs		Planted Shrubs		Invaded Species		Invaded Grasses		Invaded Forbs	
	F	PR>F[2/]	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F	F	PR>F
Substrate	0.07	0.7984	0.01	0.9082	0.00[3/]	0.9830	0.68	0.4135	0.02	0.8791	4.06*	0.0469	2.51	0.1166	0.92	0.3398
Seeding	0.90	0.4120	1.47	0.2355	0.33	0.7201	5.62*	0.0050	1.58	0.2124	16.63*	0.0001	7.27*	0.0012	8.94*	0.0003
Mulch	1.26	0.2873	1.35	0.2657	1.96	0.1470	0.96	0.3866	1.20	0.3053	0.59	0.5543	0.92	0.4021	0.13	0.8745
Substrate x Seeding	0.04	0.9597	0.03	0.9675	6.65*	0.0020	2.13	0.1246	0.32	0.7265	1.38	0.2571	0.75	0.4745	0.46	0.6347
Substrate x Mulch	0.47	0.6245	0.32	0.7238	1.59	0.2091	0.63	0.5326	0.71	0.4935	5.19*	0.0074	3.92*	0.0233	0.83	0.4414
Seeding x Mulch	0.44	0.7797	0.37	0.8280	0.72	0.5816	1.31	0.2713	0.59	0.6679	1.14	0.3436	1.33	0.2664	0.05	0.9960
Substrate x Seeding x Mulch	0.74	0.5692	0.77	0.5471	3.45*	0.0013	0.57	0.6855	1.13	0.3489	4.82*	0.0014	3.43*	0.0116	0.72	0.5819

[1/] Complete analyses are presented in Appendix 6-2.4

[2/] PR>F represents the significance probability (α) associated with F.

[3/] F value could not be detected in computer at 2 significant decimal places

* ($\alpha = 0.05$)

One would expect biomass determinations to follow the same trend as that for cover estimates. However, biomass differences for some categories (planted grasses and shrubs, all planted species, and all species) were not found to be significant for the main effect seeding intensity (Table 6-8). Shrub tubelings were planted uniformly within the three seeding regimes. Therefore, it is probable that these shrubs have obscured any significant differences that may have been present for both the planted shrub and planted species categories. It is unclear why significant differences were not evident for planted grasses. Significant differences also were evident for one other main effect and several first and second order interactive effects. Total biomass of invaded species was significantly higher ($\alpha = 0.05$) (average 60 kg/ha) on the shale substrate than on the no shale substrate (average 37 kg/ha). However, partitioning invaders into graminoids and forbs provides more meaningful information, and neither invaded grasses nor invaded forbs considered alone exhibited significant differences (Table 6-8). The substrate x mulch and substrate x seeding x mulch interactions for invaded species and invaded grasses were also significant ($\alpha = 0.05$). Further study may help to clarify these interactive effects.

c. Precipitation - Precipitation at the three revegetation sites (R1, R2, R3) averaged 6.04 inches from April through October, 1979 (Table 6-9). The greatest volume of precipitation (2.71 in) was recorded during May, whereas the lowest (0.44 in) fell during September. The 1979 precipitation value represents a 21 percent increase over the 4.74 inches recorded for the same period in 1978 (RBOSC 1979).

Data from Meteorological Monitoring Site 2 (Appendix 2-2.4) indicate that annual precipitation is approximately 14.0 inches. Site 2 data also show that, between June 6 and July 16, 1979, there was no precipitation whatsoever. Adequate moisture during May combined with irregular rainfall in early-to-mid-summer suggests that, to be successful, spring seeding efforts should be undertaken in April or early May. However, extended periods with no precipitation, such as noted above, may reduce revegetation success during some years.

d. Electrical Conductivity - Electrical conductivity determinations were made at four locations on Site R3 during 1979. Conductivity averaged 1.1, 1.6,

Table 6-9. Rainfall (inches) Recorded at the RBOSC Revegetation Sites (R1, R2, R3) from April through October 1979

Month	R1		R2		R3		Average
	Upper	Lower	Upper	Lower	Upper	Lower	
April	0.48[1/]						.48
May	2.71[1/]						2.71
June	0.48[1/]						.48
July	0.81[1/]						.81
August	0.94	ND	0.89	0.93	0.87	0.83	.89
September-October 2	0.43	ND	0.45	0.35	0.52	0.46	.44
October 2-31	0.84	ND	1.24	0.97	1.12	1.02	1.04
Total							6.04

[1/] Data from wedge gauge at Meteorlogical Site 2 (see RBOSC MDP Monitoring Report 4 for April and May values and Appendix 2-2.4 of this report for June and July values)

and 1.5 mmhos/cc at 0, 25, and 50 cm on the shale substrate portion of the plot. Corresponding values for the no-shale portions were .85, 1.1, and 2.45 (Table 6-10). During 1978, average electrical conductivity at 0, 25 and 50 cm on the shale treatment was 0.26, 0.28, and 0.40. Corresponding conductivities on the no-shale control treatment were 0.28, 0.27 and 0.42. Different sampling techniques and locations were employed during 1979, and these factors undoubtedly account for the noteable increases between conductivity recorded this year relative to previous sample periods. A comparison of techniques will be conducted during 1980 to test this supposition. In addition, tests will be run to determine if trace metals and/or potentially toxic substances are being assimilated by the plants.

Table 6-10. Average Electrical Conductivity (mmhos/cc)[1/] of Soils Sampled at Three Depths (0, 25, 50 cm) at RBOSC Revegetation Plot R3 During Fall 1976, 1977 1978 and 1979, Tract C-a[2/]

	Substrate							
	Processed Shale				No Processed Shale			
Depth	1976	1977	1978	1979	1976	1977	1978	1979
0	.28	.20	.26	1.10	.26	.20	.28	.85
25	.38	.26	.28	1.55	.31	.26	.27	1.10
50	.45	.50	.40	1.50	.56	.57	.42	2.45

[1/] based on a 1:2 soil-water extract

[2/] 1979 data differ in sampling technique, location, and number of replications and, consequently, are not directly comparable to data from previous years.

6.3 SUBSIDENCE

Subsidence monuments were surveyed during May--June 1979 following methods described in Section 7.3 of the MDP Environmental Monitoring Program -- Revision 5.2. No movement of any surveyed monuments was detected. Monument D-12 was removed in order to clear the scrubber pond area. Locations of monuments were presented in RBOSC MDP monitoring Report 4 (Appendix 6-3.1). Monument locations will be surveyed again in December 1979, and results will be presented in monitoring report 6.

6.4 RUN-OF-MINE LYSIMETER

Negotiations among RBOSC and several federal agencies resulted in an agreement to conduct leaching studies on stockpiled run-of-mine. RBOSC will construct three lysimeters and maintain them for three years, the USGS will pick-up and split collected leachate, and the EPA will conduct chemical analyses of the samples. The AOSO will coordinate construction and sample collection and distribution. The lysimeters will be constructed in early 1980 and will collect leachate from depths of 5, 10, and 15 ft in the run-of-mine pile. The leachate will contact only teflon in the lysimeters to allow for complete organic analyses.

Results of the run-of-mine leachate study should provide information on the characteristics of leachate from stockpiled raw ore shale.

6.5 SUMMARY

Special Studies reported for the period December 1978 through November 1979 include toxicology, revegetation, subsidence and run-of-mine lysimeter programs.

RBOSC, in cooperation with the DOE Oil Shale Task Force, is arranging for a series of toxicology tests on Tract C-a materials. Concurrently, raw ore samples representative of MIS retort materials will undergo chemical characterization by the Union Oil Company Research Institute to establish the need for future toxicological testing.

Revegetation study Site R3 was monitored for vegetation coverage, above-ground biomass, precipitation, and electrical conductivity of soils during 1979. Coverage and biomass were determined within eighteen treatment combinations (108 sample sites).

Coverage of grasses and shrubs increased whereas that of forbs decreased relative to 1978 data. Wheatgrass, Indian ricegrass, cicer milkvetch, winterfat, and four-winged saltbush were the dominant species contributing to an average cover of 52 percent. Seeding rate (main effect) resulted in significant differences in coverage for all growth form categories tested. Substrate and mulch (main effects) and various interactive effects were found to be of significance in a limited number of cases.

Average biomass also increased relative to 1978 values, and totaled 2151 kg/ha during 1979. Grasses and shrubs provided the majority of this material, 838 and 1258 kg/ha respectively. High biomass values for shrubs were due, in part, to inclusion of woody stems in the determinations. Production available for forage would be considerably lower.

Precipitation during the 1979 growing season was greater than that for 1978. The majority of precipitation occurred during May, and there was a period of drought from early June through mid-July. Electrical conductivity of soils increased relative to previous years; however, this increase is probably related to differences in sampling techniques.

Data from 1979 demonstrate that, after three years, revegetation efforts have resulted in coverage and biomass which exceed that of naturally occurring plant communities on Tract C-a. Furthermore, no significant differences in total coverage or biomass have been noted between spent shale and no-shale substrates. Data collected thus far suggest that RBOSC's artificial soil profile over spent shale provides a suitable growth medium which can be used for reclamation of wastes generated by an oil shale operation.

Subsidence monuments were surveyed during May - June 1979, and no movement was detected. One monument was removed in order to clear the scrubber blowdown pond area.

Leaching studies on stockpiled run-of-mine ore will begin on Tract C-a during 1980. These studies are being conducted in cooperation with USGS, EPA, and the AOSO, and will continue for a period of three years. Leachate will contact only teflon and, consequently, can be used for complete organic analyses.

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SECTION 7
ECOLOGICAL INTERACTIONS

The identification and quantification of ecological interactions on the oil shale lease tracts and the surrounding terrain is an intriguing challenge. RBOSC and other oil shale lessees have been seeking a better understanding of these interactions for quite some time. These efforts are confounded not only by the complexity of the ecosystems under study, but also by the sheer size of the study areas -- in excess of 81 sq mi in and around Tract C-a.

Ecological interactions are not measured or monitored directly. Instead, they are identified through a systematic time-consuming process involving the identification of effector and receptor components, collection of monitoring data, assimilation, feedback, and analysis. RBOSC's environmental monitoring program is providing data on a number of major ecosystem components, however it is not possible to measure all ecosystem interactive components.

The statistical analyses of interacting components must often be delayed until an adequate data set has been accumulated. This is especially true for biological parameters which must be segregated into logical functional groups (e.g. seasons, years, reproductive phase, etc.) before meaningful analyses can be accomplished. In addition, in a study area as large and complex as RBOSC's area, several years of data are required to detect even minor changes.

Assimilation and synthesis of data for this and previous reporting periods has begun to confirm conceptual models developed from baseline data (RBOSP 1976 - Final Environmental Baseline Report) and to reveal certain (tentative) trends. Many of these trends are discussed specifically and at greater length in the various technical sections of this report. Those of special interest are discussed below.

Of the large number of events expected to influence the dynamics of the tract ecosystems, three have been isolated because their effects can be measured or observed readily. They are:

- Between-year and seasonal climatic variations
- Man-induced changes in hydrologic regime

- Increases in human activity

There is no question that tract ecosystems are subjected to more influences than those just listed. However, these variables are more identifiable than many others, and probably represent the major sources of variation in the system that have occurred since baseline studies were initiated. Ecosystem changes associated with removal of habitat (clearing) are obvious. The amount of habitat removed during the MDP is small when compared to the size of the tract and the basin, therefore it is not feasible to address these interactions at this time.

7.1 BETWEEN YEAR AND SEASONAL CLIMATIC VARIATIONS

The 1978-79 winter season was characterized by early snowfall, continued accumulation throughout the winter, and a late snow-melt. The first major snowfall occurred in November -- the last one of the season in April. The snow cover was continuous throughout most of this period, with accumulated depths in excess of four feet over much of the area. Lower than average temperatures (4-5 C lower than the average in 1978) were reported at the main meteorological station and elsewhere throughout the area in 1979.

This deep, long-lasting snowcover was the most severe reported for the tract area since the RBOSC data accumulation program began in 1974. Similar conditions were reported throughout the western part of the United States and in the Colorado mountains.

Early in the winter of 1978-79, there was a large increase in snowfall compared with the previous year (November and December of 1978 had 75 percent more precipitation that November and December of 1977). Coupled with the much lower average temperatures during the December 1978 - February 1979 period, this resulted in a larger snowpack and increased spring runoff. The immediate effects of this late-lying snow were exhibited as increased spring runoff at the USGS surface gaging and aquatic sampling stations in the area. A generalized illustration of the potential interaction related to this type of year-to-year variation is presented in Figure 7-1: Rapid spring thaws result in heavy stream flows which in turn dilute the dissolved solids, increase the sediment load, and enhance erosion. Erosion of the stream channel scours the substrate and washes away resident biotic communities. These communities are later replaced by different populations, better adapted to the silt-free habitat. In the terrestrial system, the late-lying snowpack increases available soil moisture and favors germination and production of grasses. For example production in the upland sagebrush vegetation type increased from 79 kg/ha in 1978 to 101 kg/ha in 1979.

Data collected to date tend to support this generalized qualitative model. However, the simplicity and preliminary character of the model limit its usefulness.

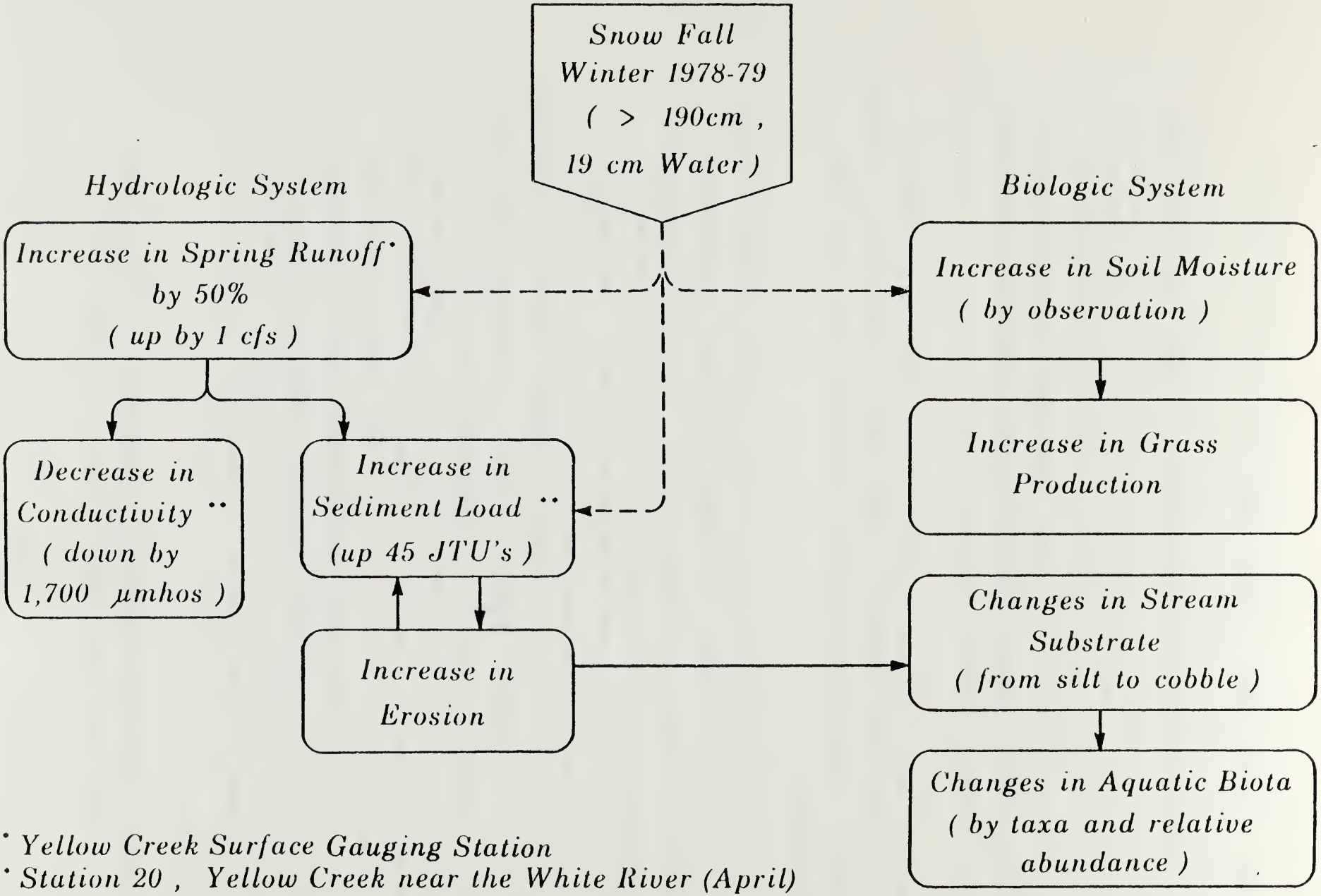


Figure 7-1. Possible Interactions Among Climatic (Snowfall), Hydrologic, and Biologic Systems, Winter-Spring 1978-79, Tract C-a

Well-known and accepted ecological principles have merely been reconfirmed. The utility of the model rests with the replication of the process. When long-term (at least six years), comparable, replicate data become available, it will be possible to statistically analyze various interacting components. This model will serve as the basis for these future analyses.

Increased snow depth during the winter (1978-79) forced deer from the tract to lower elevations and restricted the movements of those remaining to ridge tops, south-facing slopes, and valley bottoms adjacent to these slopes. This behavioral pattern (Figure 7-2) is confirmed by visual observations by the RBOSC field biologist, preliminary pellet count data, and browse use data. The increased solar radiation on south-facing slopes, and higher winds typical of ridge tops, decreased the snowcover in these areas. The reduced snowcover and protection provided by pinyon-juniper vegetation attracted deer. Subsequently, available browse was more heavily utilized in the pinyon-juniper habitat (15%) than in areas less favorable to deer -- upland sagebrush (4%). However, browse data for the pinyon-juniper habitat type indicate that both pinyon pine and sagebrush were more heavily browsed in 1977-78 than in 1978-79. The difference in use of sagebrush was significant at the 95 percent probability level; the use of pinyon pine was significant at the 90 percent probability level. This confirms other data which suggest that, in general, the overall use of the study area by deer was down in 1978-79 because they had moved to lower elevations. Potential interactions shown in Figure 7-2 can be investigated further by correlation analyses once sufficient data (minimum of 6 years) become available. Multivariate analyses over a period of several years may also be useful in the study of these interacting variables.

The possible interaction between the heavy snowcover of 1978-79 and the small mammal population is illustrated on Figure 7-3. Trapping data for the spring of 1979 indicate a boom in small mammal numbers, particularly the deer mouse. Small mammal data were not collected in the spring of 1978. However, the number of small mammals per 100 trap nights for the two baseline years, in similar habitat types, was substantially lower than the number trapped in 1979. These data may be biased by a number of factors including: natural fluctuations in small mammal populations; differences in sample size, sampling frequency,

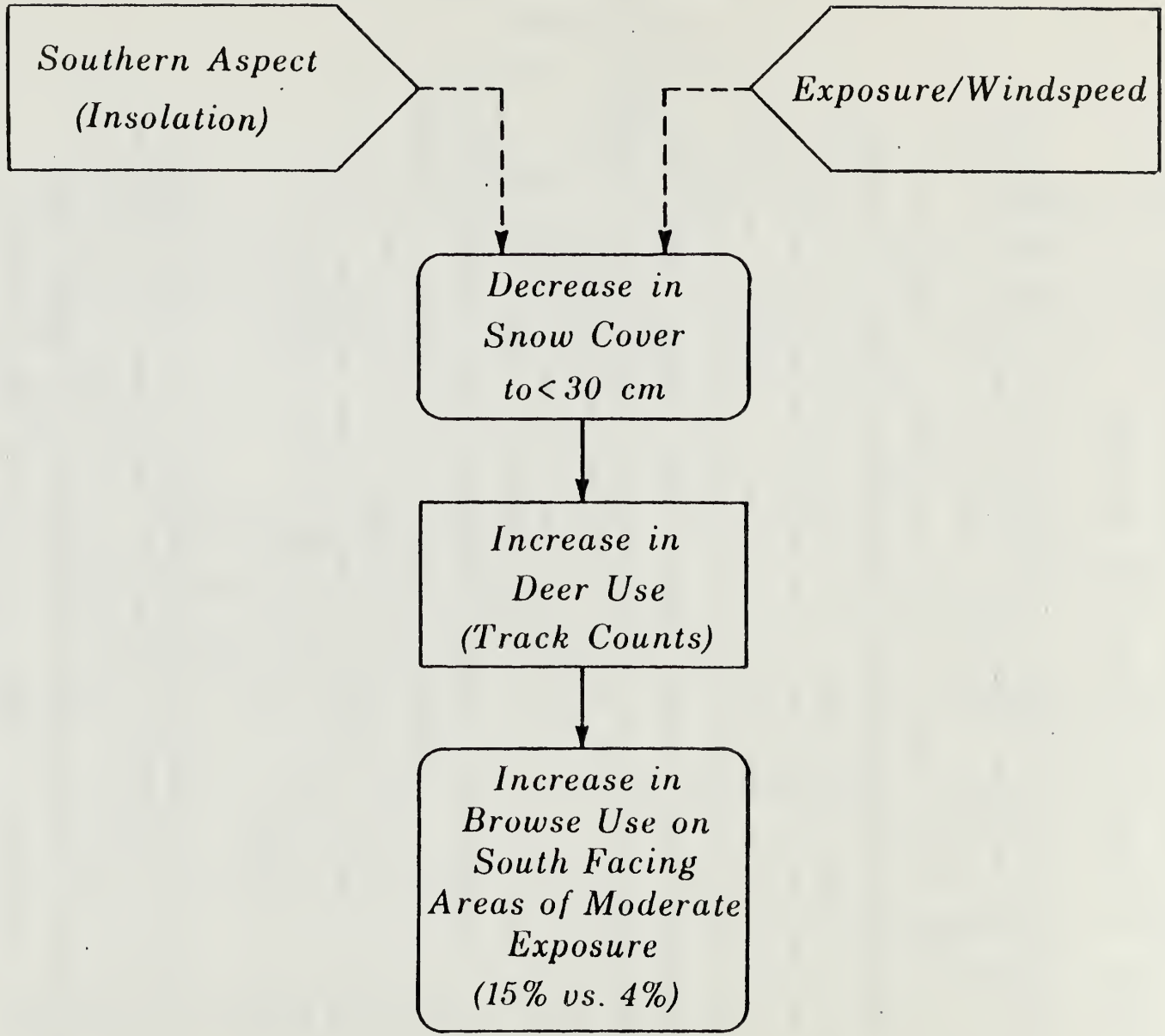


Figure 7-2. Possible Interactions Among Snow Cover, Deer Distribution, and Browse Use in Pinyon-Juniper Habitat, Winter 1978-79, Tract C-a

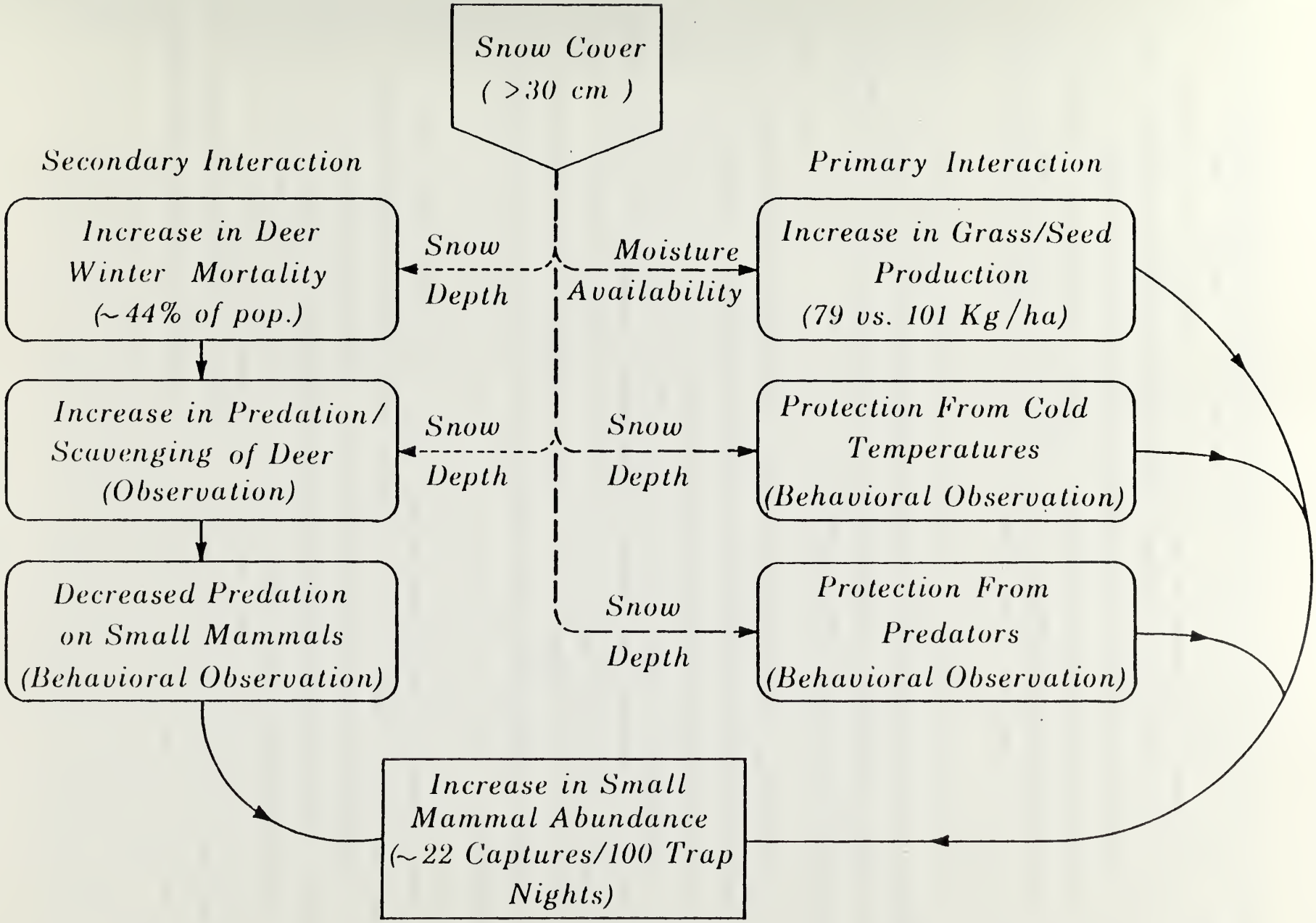


Figure 7-3. Possible Interactions Between Snow Cover (1978-79) and Small Mammal Abundance (Spring 1979), for Upland Sagebrush Habitat, Tract C-a

and sampling location; and variations in sampling technique. Therefore, this conceptual model is tentative, at best. The interaction is complex. Small mammals, unlike deer, are favored by deep, long-lasting snowcover. It provides both insulation (protection from extreme cold) and protection from predators. Increased survival over winter is complemented by improved habitat in the spring when grasses respond to available soil moisture with increased production. Some small mammal species may produce several litters during the spring and summer when food is adequate. Seed production by the good grass crop provides adequate forage.

A secondary interaction, although unconfirmed, can be postulated. Predation on small mammals may have been reduced because of the abundance of deer carcasses or weakened deer available for easy predation.

The spring of 1979 was a relatively moist period, even though a 38-day period with no measurable precipitation occurred during June and July. One might expect that such an extended dry period could adversely affect revegetation success and production of range forage. It is too early to judge success of revegetation on disturbed lands. However, Experimental Revegetation Plot R3 did quite well in 1979, with total cover measured in September averaging nearly 52 percent for the summer period. Perhaps vegetation in the three-year old plot was well enough established to withstand the 38-day dry period without adverse effects.

Interactions between air quality and seasonal meteorological variations are discussed thoroughly in Section 2.1. Suspended particulates are significantly affected by temperature and snowpack (Section 2.2), but the relationship is obscured by a number of other factors, including location of the sample site. Any relationships between biotic components and air quality parameters are too tentative to discuss at this time. Air quality has remained practically unchanged from baseline. Once tract sources of gaseous and particulate emissions become important, these interactions may be more distinct and will be investigated further.

7.2 MAN INDUCED CHANGES IN HYDROLOGIC REGIME

During the reporting period, a series of tests was conducted in an effort to improve the mine dewatering system. This resulted in an intermittent discharge of upper aquifer water (removed from dewatering wells and mine inflow) to surface drainages. Flows up to 4.5 cfs were recorded at the Corral Gulch gaging station during these discharges. This represents an increased annual runoff over previous years.

A detailed analysis was conducted on the behavior of flows and chemical characteristics at the Corral Gulch East gaging station (D), because of the strategic location of this station immediately downstream from the discharge point for mine dewatering water. Flow and various chemical constituents were plotted in several combinations as a means of determining the cause and effect relationships between the discharge of dewatering water and flow and quality in the stream. Conductivity plotted as a function of time, on a monthly basis showed that throughout most of the year, the conductivity was relatively constant, being around 1,250 µmhos. In April however, a sharp increase in conductivity to approximately 1,450 µmhos was seen, followed by a gradual decrease during the months of May and June back to normal values in July or August. This behavior indicates the "flushing" of chemical deposits in the upper banks of the stream during times of high runoff. These bank deposits are precipitated in the soil above normal stream level during periods of average flow. Higher than average spring run-off tends to redissolve these chemical constituents and reintroduce them to the stream, which results in a higher conductivity during this period of time. The highest conductivities are associated with flows from 2.5 to 5 cfs, corresponding to those flows associated with spring runoff, which are high enough to dissolve chemical deposits in the bank above the normal level of flow. At flows higher than 5 cfs, dilution is sufficient to decrease the conductivity. Below 2.5 cfs, conductivity decreases with flow. When conductivity was compared to discharge, it showed that at flows higher than 1 cfs, conductivities would either increase or decrease. When the dates of various points were examined it showed that increases were associated with "first flush" runoff, while lower conductivities were associated with higher flows. Apparently the "first flush" redissolves a larger portion of the salt stored in the banks of

the stream, thus increasing the conductivity. Subsequent high flows do not increase the concentration because the chemical deposits in the banks have already been dissolved and washed away by previous flows. The chemical buildup apparently occurs during parts of the year when high flows do not occur, and when evaporation tends to increase the concentration of dissolved solids in the water. These higher concentrations induce the formation of deposits in the soil along the banks of the creek.

Stream channel erosion data indicated that substantial down-cutting of the stream bed and sedimentation has occurred in Corral Gulch as a result of increased (dewatering) flows. This process is similar to natural weathering that results during intensive rain-fall events and has probably affected the aquatic habitat in a similar way.

Aquatic biota at Stations 13 and 14, near the point-discharge, continued to exhibit variation. Total cell densities for both stations were up from 1978, perhaps in response to warmer water temperatures as a result of discharge. Total cell densities were lower at the Yellow Creek and White River Stations in 1979 than in previous years. This may be related to colder water and increased scouring from the snow melt runoff.

Benthos density and diversity was uniformly lower in 1979 at all stations than recorded previously. Many factors may be involved, but the uniform occurrence indicates it may not be directly linked to tract development.

The presence of open water during the winter when normally little or no surface water is available attracted feral horses to Corral Gulch. Digestion of roughage available during the winter is facilitated by ample water.

The intermittant discharge of water into Corral Gulch accompanied by the die-off of sagebrush in the drainage bottom has led to the speculation that there may be a relationship between the two events. As the gradient becomes less pronounced, at this point in the valley, the stream widens and becomes less channelized. This wide-spreading stream pattern is detectable in aerial photographs taken as early as 1974, prior to the discharge in question. It

appears that the alluvium in this area is likely to become saturated during peak runoff periods.

Sagebrush can exist under conditions of intermittent saturation of the root zone, but may succumb if saturation is prolonged or overly frequent. Examination of color and CIR photographs taken in 1974 indicates that some patches of sagebrush in the area under discussion were dead or dying at that time. The affected area became increasingly evident during 1979. It is possible that the discharge of water into Corral Gulch typifies natural, high runoff periods and has resulted in the saturation of the alluvium on a more regular basis. In this case, the activities on Tract C-a may be increasing the rate of community succession. The ultimate community structure may consist of grass species favored by the increased moisture with a reduced incidence of sagebrush.

7.3 INCREASES IN HUMAN ACTIVITY

Human activity as a result of natural gas exploration probably increased at a greater rate during the study period than did Tract C-a activities. The combination of both development activities has without doubt introduced additional human activity into the area, both during and after working hours.

Although not confirmed, it appeared that mule deer hunting actually declined during the fall of 1979. This is probably related to the reduction in herd size because of heavy winter losses in 1978-79.

Wildlife losses resulting from collisions with automobiles have increased with increasing traffic. Losses of mule deer in lower areas during the winter 1978-79, and the spring of 1979 were noticeably up. However, they represented a very small percentage of the winter-kill.

The effects of site development activities on wildlife immediately adjacent to the area are largely unknown. Land cleared of vegetation will obviously not support as much wildlife as non-disturbed land. However, results of the mule deer pellet group counts indicate that more deer use a 9 sq mi block centered on the tract than other same size blocks within three miles of the tract boundaries. Deer and feral horses are frequently seen adjacent to the development site. Fencing is required to restrict deer activity on or adjacent to some areas. Additionally, a golden eagle successfully fledged a young eaglet from a nest adjacent to County Road 24 during paving activities.

The effects of increased human activities on wildlife in the area cannot be adequately assessed at this time. Observations will continue in an effort to determine the sources of interactions that should be addressed in greater detail.

SECTION 8
SUMMARY

In September 1977, RBOSC initiated their Modular Development Phase (MDP) Environmental Monitoring Program. The first report of MDP environmental activities (September - November 1977) was published in Feburary 1978; the second (December 1977 - May 1978) was published in September 1978; the third (December 1977 - November 1978) was published in March 1979; and, the fourth report (December 1978 - May 1979) was published in August 1979. This report, RBOSC MDP Monitoring Report 5, presents and evaluates data collected December 1978 through November 1979. The following summary addresses the atmospheric, terrestrial, aquatic, hydrologic, special studies, and ecological interaction aspects of the monitoring program. Detailed discussions pertaining to each discipline may be found in the corresponding sections of the text.

Atmospheric Studies

Both air quality and meteorological data were collected during the six-month reporting period. One unusual event occurred--the installation of an underground pipeline immediately adjacent to the Monitoring Site 1. At the peak of the construction activity, the primary 24-hr National Ambient Air Quality Standard (NAAQS) for total suspended particulates was exceeded once at the site. Ironically, this activity, which was unrelated to the development of Tract C-a, resulted in the highest measurement of total suspended particulates in four years of monitoring at the three main sites (303 $\mu g/m^3$).

The continuous monitoring system recorded only a very small number of events during which the concentrations of NO, NO_x, SO_2, H_2S, and CO were above the threshold of detection. Most of the time only ozone and total suspended particulates had concentrations above the threshold of detection.

Analysis of the four years of ozone data has shown that a diurnal cycle of relatively high ozone concentrations during the day and relatively low ozone concentrations at night is one of the most striking aspects of the data. This cycle has a much greater magnitude at Site 3. Review of the data indicates that the mechanism for this phenomenon is a nocturnal inversion which commonly develops over the gulch where Site 3 is located. This inversion effectively isolates the site from the relatively ozone-rich air present above the lowest

boundary layer. After the inversion forms, typically around sunset, much of the ozone remaining in the ambient air trapped within the gulch is destroyed during the night by surface reactions. The breakup of the nocturnal inversion shortly after sunrise allows replenishment of the ozone in the gulch from upper levels. At Site 1, the diurnal cycle is greatly reduced because the location near the top of a hill is not conducive to the formation of a nocturnal inversion.

This hypothesized mechanism explains most of the observed variations in the local ozone concentrations, with the exception of the annual summer peak commonly found at many rural sites. There is no evidence of local photochemical production from either natural or anthropogenic sources. Thus, tract development to date appears to have had no effect on the ambient ozone levels.

Ozone concentrations do occasionally reach or exceed 0.080 ppm, primarily during the summer, but have never been recorded at levels approaching the NAAQS for oxidants (0.12 ppm). Concentrations comparable to those measured at Tract C-a have been found at many rural sites throughout the United States. The exact source of these relatively high ozone levels is currently the subject of active research.

The only verifiable air quality change to date is the increase in particulate concentrations. The 24-hour secondary NAAQS for particulates was exceeded once at Site 3 (the treatment site downwind from the main tract development area) during the current year. However, a stepwise multiple regression analysis showed that the high particulate levels at Site 3 were more closely associated with meteorological conditions (high temperatures and low precipitation) rather than any measure of tract activity.

Several statistical analyses were performed on the particulate data sets, including correlations, multiple regressions, stepwise multiple regressions, and analysis of variance. It was found that the particulate concentrations measured at the tract could be divided into two periods with minimum overlap: 1) the winter season (the period with a semi-permanent snow cover), and 2) the summer season (the period with no snow cover). The statistical analyses were carried out on the winter, summer, and combined yearly data sets.

The correlation analysis showed that Sites 1 and 2 (the control sites generally upwind of the main development area) were the most highly correlated ($r = 0.84$ for the current year), whereas Sites 1 and 3 were the most weakly correlated ($r = 0.62$). There was little seasonal effect on the corrections.

The multiple regressions showed that approximately two-thirds of the variation in particulate concentrations could be explained by a combination of meteorological and site activity variables. Stepwise regressions indicated that, for the summer and combined data sets, the important factors in explaining the variation in particulate concentrations at Sites 1 and 2 were meteorological variables (i.e., precipitation, wind speed, and temperature). None of the site activity variables made significant contributions to the regression equations for these data sets.

At Site 3, an indicator of development activity was a significant variable in the regression, but it ranked no higher than third in importance of explaining the variation in particulate concentrations. Thus, development activity apparently had an impact on particulate concentrations only at Site 3 in the summer and yearly data sets. The regressions on the winter data set generally were not as successful in explaining the variation in particulate concentrations. This is probably due to the lower particulate levels and the much lower variation, which decreases the reliability of the regression analysis.

Comparison of the meteorological data set for the current year with the previous year's data set has revealed that the meteorology is very similar. The only exception is precipitation which, at 14 to 15 inches (the best estimate based on eight precipitation gauges), is the highest of the four years on record. The temperature range of 60 C (-30 C to +30 C) found during the current year is typical of continental sites. Wind speed at the tract has been relatively low, reaching a maximum of only 37 mph at the 10-m level. After four years of monitoring, RBOSC is beginning to develop a reasonable climatological record, although no long-term means can yet be determined.

The 1979 visibility program did not indicate any change in visual ranges in the Piceance Creek Basin. The mean annual visual range for 1979 was 80 miles,

compared to 79 miles during the two previous monitoring years, 1978 and 1975-76. There is a large day-to-day variability in the visual range, but this is primarily a result of widely varying meteorological conditions. The maximum visual range of 154 miles, measured during the three years of monitoring, occurred in 1979. Visual ranges near 150 miles were also recorded during the two earlier years of monitoring. This value approaches the theoretical limit of visual range in the atmosphere (200 miles).

Two noise surveys were taken during the reporting period. The measured sound levels generally ranged from 25 to 50 dBA, except near the main construction area (adjacent to the headframe), which averaged 77 dBA. If the measurements taken near the main construction area are excluded, these sound levels are comparable to data taken during the baseline period.

Terrestrial Studies

The components of the Terrestrial Monitoring Program examined during the December 1978 through November 1979 reporting period include vegetation mapping and stress, phytosociological, range production and utilization, browse utilization and condition, small mammal, avifauna, mule deer, and feral horse studies.

Color infrared photographs from 1974 were studied and "moist pockets" identified. Comparisons with 1979 photographs indicated that those areas identified from 1974 photography also were evident during 1979. Preliminary determinations suggest increases in moisture balance in some areas. These increases may be attributable to natural variations between years in many instances. However, increases noted in several portions of Corral Gulch, and one location in Box Elder Gulch, seem to be related to reinjection and/or dewatering discharge. Although vegetation changes have not been observed within each of these areas, expected changes would be reductions in bottomland sagebrush and increases in grass communities.

Phytosociological studies were conducted on 10 transects (5 control, 5 treatment) within the pinyon-juniper habitat type on and adjacent to Tract C-a. Coverage of trees and shrubs was similar between the study areas, but density of woody

species was greater within the treatment area. Herbaceous vegetation averaged 13.7 percent coverage in the control area and 14.8 within the treatment area. There was no significant difference ($\alpha = 0.05$) in herbaceous coverage between areas. Graminoid species were the dominant contributors to herbaceous coverage in both areas. Bluegrass (Poa spp.) and Indian Ricegrass (Oryzopsis hymenoides) were the most prevalent grass species observed.

Range productivity and utilization studies indicated that production varied from 44 kg/ha in the pinyon-juniper to 209 kg/ha in the mixed brush habitat type. Production within the mixed brush and pinyon-juniper types was similar to that recorded in 1978, but increased significantly ($\alpha = 0.05$) within the sagebrush type. Relative to 1978, percent utilization increased in the mixed brush type, and decreased within both the pinyon-juniper and upland sagebrush types. Graminoid species were used more heavily than were forbs in all three vegetation types. Data indicate that variability in both production and utilization is inherent within the ecosystems being studied. Therefore, definitive trends for production and/or utilization cannot be ascertained at this time.

Browse condition and utilization data show that average utilization decreased between 1978 and 1979 within the pinyon-juniper and upland sagebrush vegetation types, whereas utilization for the mixed brush type remained about the same. Mountain mahogany (Cercocarpus montanus) use increased significantly ($\alpha = 0.05$) within the mixed brush type in 1979, but decreased significantly ($\alpha = 0.05$) within the pinyon-juniper type. Sagebrush (Artemisia tridentata) utilization was significantly greater within the pinyon-juniper type in 1979, and significantly lower ($\alpha = 0.05$) in the upland sagebrush type. Browse use ratings were similar to those reported for 1978, and indicated that, for the most part, utilization values were "acceptable" for average winter-range. Browse condition also was similar to that for 1978 and ranged from "poor" to "good" depending on the species and/or vegetation type being considered. RBOSC browse data are based on consideration of the same individual plants on a yearly basis and, consequently, do not reflect changes in age structure of browse species which may be taking place. Therefore, one should take caution in making basin-wide generalizations based on these data.

Four small mammal species were captured during the 1979 sampling period. The deer mouse was the most frequently trapped species in both pinyon-juniper and sagebrush habitats in both the treatment and control areas. The least chipmunk was the second most frequently caught. These species were also the most frequently caught during baseline studies. The ratio of deer mice caught per 100 trap nights during the sampling period for all areas was higher than that ratio during baseline. Small mammal populations normally fluctuate widely, and the high deer mouse population may have been related to the deep snow which covered the ground for much of the previous winter. The deep winter snows may have provided protection from adverse weather and predators and ample moisture for a wet spring which then resulted in greater vegetation production in some locations. The high trap success for deer mice may have reduced the number of captures of other small mammal species because a trap with an individual in it is incapable of capturing other individuals of the same or other species.

More species of birds were observed in the pinyon-juniper habitat than in the sagebrush habitat in both the treatment and control areas. This distribution was also noted during baseline studies. A total of 12 bird species was observed in the treatment area, and 12 species also were observed in the control area of the pinyon-juniper habitat type. A total of four bird species was observed in the treatment sagebrush habitat, and six were observed in the control sagebrush type.

The most frequently sighted species in the pinyon-juniper habitats were the chipping sparrow and the black-throated gray warbler in both treatment and control areas. Other frequently observed species in the pinyon-juniper habitat were the brown-headed cowbird and the mountain bluebird (treatment area) and Brewer's sparrow, the green-tailed towhee, and the common raven (control area). In the sagebrush habitat, the most frequently observed species were Brewer's sparrow and the green-tailed towhee in both treatment and control areas. The sage thrasher was frequently seen in the sagebrush habitat in the treatment area, but was not observed in the control area. There appeared to be little correlation between the bird populations in the same habitat type in the treatment versus the control areas. Similar variability between bird populations in the same habitat types were noted during baseline studies.

Based on pellet group counts, mule deer use in 1979 was not significantly different ($\alpha = 0.01$) in the area north and northwest of the tract than in other parts of the study area. If the numbers of pellet groups are extrapolated to represent numbers of deer, about 50.9 and 43.2 deer per square mile were on the RBOSC study area during the winters of 1977-78 and 1978-79, respectively. These numbers are similar to estimates by the Colorado Division of Wildlife (52.4 and 43.6 deer per square mile) for the same years.

Only 10 deer were killed by collisions with vehicles along Rio Blanco County Road 24 during the spring and fall (through November) migration period in 1979. Deer were very numerous along this road during the Spring period, accounting for 9 of the 10 deer killed. The number of road kills is low considering the heavy traffic and poor road conditions during that time.

A total of 99 feral horses in 21 bands was counted in the 81 sq mi study area in January 1979. During the foal count in September, it was estimated that about 16 percent of the feral horse population in the area was composed of young-of-the-year.

No threatened or endangered species were observed in the vicinity of Tract C-a during the reporting period. A protected species, the golden eagle, nested and successfully fledged one chick near Rio Blanco County Road 24 during the summer.

Aquatic Studies

Physical parameters examined at each of the aquatic sampling stations indicate both seasonal and annual variability. Few trends or major changes in the physical measurements can be detected from the data. Sampling Stations 13 and 14 showed an increase in the volume of flow. This increase is hypothesized to be the result of operational discharge of water into Corral Gulch, which in turn increased the depth, width, and velocity of water at Stations 13 and 14. A slight increase in conductivity and turbidity was noted at Station 13, presumably as a result of water discharge into Corral Gulch. Physical data collected to date do not lend themselves well to statistical analyses because of the high

degree of seasonal and annual variability exhibited by aquatic habitats in the area, and lack of adequate long-term information. Changes or trends in physical data, utilizing such techniques as trend analysis, time series analysis, and cluster analysis, will be studied as soon as adequate data become available.

Water quality measurements made in 1979 indicate no large changes in White River water quality above or below its confluence with Yellow Creek. Examination of the 1979 data and data collected in the baseline and early monitoring phase, analyzed with standards established by EPA procedures, also shows no detectable differences in water quality or aquatic sampling stations on or near Tract C-a.

The 1979 total mean periphyton density for all aquatic sampling stations was 2698 units/mm^2. Mean density values ranged from a high at Station 14 (6446 units/mm^2) to a low at Station 29 (411 units/mm^2). Annual variations in periphyton densities are large on a monthly basis, and are directly related to such highly variable environmental parameters as light, temperature, current velocity, spring run-off, turbidity, and substrate type.

Generally, 1979 densities, diversities, and biomass estimates were somewhat lower than 1978 and 1977 values. Periphyton were dominated by Achnanthes spp., primarily Achnanthes minutissima, at Station 13 during the baseline period, while Phormidium spp. dominated during the spring and early summer and Achnanthes spp. dominated during the fall of 1979. This change in dominant species may be due to the increase in turbidity and flow of water at Stations 13 and 14 during the spring. Variations in species dominance is not uncommon in aquatic community structures with a high degree of variability such as increased turbidity and velocity. Change in dominance of one species over another is frequently seen within variable physical environments. When more data are collected, in future years, the question "Are there any significant changes in the correlation between dominance by particular species and associated physical measurements?" can be addressed and tested statistically. All that can be stated to date is that changes (not accounted for by seasonal variations), may have occurred in the periphyton communities since the baseline period. Further examination over a longer time period is warranted.

Benthos samples collected from Stations 13 and 14 in 1979 indicate a decrease in the number of representative taxa and total numbers of macroinvertebrates, probably due to increased turbidity and water velocity which results in habitat modification, stream erosion, and scouring of the gravel and sand substrate. An increase in Baetis sp. and the Plecopteran family Capmidae was noted in 1979 indicating a slight recovery in the numbers of these organisms from 1978 at Stations 13 and 14. Considerable habitat alteration at Station 14 over the years has resulted in a change in basic species composition from pond-like genera, such as Callibaetis, to a silted pond-like habitat taxa, such as members of the class Oligochaeta. Differences in life history strategies indicate that Callibaetis survive in a solid non-depositional substrate habitat, while the Oligochaeta thrive on a silted highly depositional habitat.

The macroinvertebrate communities of Stations 20 and 21 were fairly consistent between 1974 and 1978. A slight decrease in density and diversity was seen in 1979. This may have been caused by the flash flooding experienced in late 1978, which resulted in considerable substrate scouring and removal of macroinvertebrates. Stations 27 and 29 have shown slight differences between baseline and MDP monitoring. In general, there appear to be few, if any, changes in the benthos communities of Stations 20, 21, 27, and 29 due to mining activities on Tract C-a.

Statistical analysis of the benthic sampling program is presently limited to relative abundance, density, and diversity measurements. The procedures are limited to annual comparisons and cannot give an overall, long-term picture of the changes in benthic community structure. When a minimum of six years data are collected, analysis of the benthos community by cluster techniques and nonparametric ranking procedures will be appropriate and useful. Use of these procedures for examination of long-term changes in the benthos will give a better understanding of the effects of mining and physical and water quality changes on the benthic community.

Hydrology Studies

The hydrology program provides data necessary to satisfy lease stipulations and conditions of approval from the AOSO; assess impacts of dewatering and

reinjection (development activities); provide input to engineering design of the mine and water handling system; supply information necessary for environmental disciplines to determine if mitigative measures are necessary; and collect data for compliance with permit stipulations. The hydrology program supplements baseline data which was initiated in 1977 and is used as a means of providing current data for comparison purposes. Stream gaging and erosion stations, springs and seeps, alluvial and deep aquifer holes, surface water impoundment, discharges, and reinjection and dewatering wells are monitored.

The results of the hydrology program are summarized below:

- Surface Water - Of the six gaging stations, two, Rinky Dink Gulch and Dry Fork, failed to show any flow during the reporting period. The natural flows for 1979 were similar to those for 1975 and 1978. The discharge of excess water affected the flows in Corral Gulch, but the discharge attenuated in Yellow Creek way above Yellow Creek gaging station. The leading edge was monitored during discharge periods.

  Examination of the water quality data collected at surface gaging stations during 1979 indicates that concentrations of many constituents were statistically different from baseline data.

- Springs and Seeps - Flow at all the springs was highly variable during the reporting period. Temperature conductivity and pH varied somewhat.

- Alluvial Groundwater - Many of the alluvial wells remained dry throughout the reporting period similar to baseline. Water levels in alluvial wells on Corral Gulch were influenced by discharge of dewatering water. For the wells where data were available, differences between baseline and reporting period values of chemical concentration occurred for some parameters.

- Upper and Lower Aquifer Water - The cone of depression from dewatering the upper aquifer is elliplical with major axes to the north and northeast. Natural recharge occurs in the west and northwest portions of the tract. Reinjection is taking place in the northeast corner of the tract. The lower aquifer has not shown any response to dewatering; however, it shows a small response to reinjection in the northeast corner of the tract. Chemical data for deep aquifers taken during 1979 exhibit statistical differences from baseline data for several parameters.

- Development Activities - Flow data taken during the reporting period reflect discharges to Corral Gulch during the pump testing program. Likewise erosion data indicate that discharges to Corral Gulch resulted in minor changes of the stream channel profiles.

  Subsurface disposal permit data have been reported monthly since the onset of the testing program. These reports are available through the Colorado Department of Health and data are included in this report.

  Data taken in compliance with the NPDES permit were reported quarterly during 1978. These reports can similarly be obtained from the Colorado Department of Health and a summary is contained in the report.

Special Studies

Special Studies reported for the period December 1978 through November 1979 include toxicology, revegetation, subsidence and run-of-mine lysimeter programs.

RBOSC, in cooperation with the DOE Oil Shale Task Force, is arranging for a series of toxicology tests on Tract C-a materials. Concurrently, raw ore samples representative of MIS retort materials will undergo chemical characterization to establish the need for future toxicological testing.

Revegetation study Site R3 was monitored for vegetation coverage, above-ground biomass, precipitation, and electrical conductivity of soils during 1979. Coverage and biomass were determined within 18 treatment combinations (108 sample sites).

Coverage of grasses and shrubs increased whereas that of forbs decreased relative to 1978 data. Wheatgrass, Indian ricegrass, cicer milkvetch, winterfat, and four-winged saltbush were the dominant species contributing to an average cover of 52 percent. Seeding rate (main effect) resulted in significant differences in coverage for all growth form categories tested. Substrate and mulch (main effects) and various interactive effects were found to be of significance in a limited number of cases.

Average biomass also increased relative to 1978 values, and totaled 2151 kg/ha during 1979. Grasses and shrubs provided the majority of this material, 838 and 1258 kg/ha respectively. High biomass values for shrubs were due, in part, to inclusion of woody stems in the determinations. Production available for forage would be considerably lower.

Precipitation during the 1979 growing season was greater than that for 1978. The majority of precipitation occurred during May, and there was a period of drought from early June through July. Electrical conductivity of soils increased relative to previous years; however, this increase is probably related to differences in sampling techniques.

Data from 1979 demonstrate that, after three years, revegetation efforts have resulted in coverage and biomass which exceed that of naturally occurring plant communities on Tract C-a. Furthermore, no significant differences in total coverage or biomass have been noted between spent shale and no shale substrates. Data collected thus far suggest that our artificial soil profile over spent shale provides a suitable growth medium which can be used for reclamation of wastes generated by an oil shale operation.

Subsidence monuments were surveyed during May - June 1979, and no movement was detected. One monument was removed in order to clear the scrubber blowdown pond area.

Leaching studies on stockpiled run-of-mine ore will begin on Tract C-a during 1980. These studies are being conducted in cooperation with USGS, EPA, and the AOSO and will continue for a period of three years. Leachate will contact only teflon and consequently can be used for complete organic analyses.

Ecological Interactions

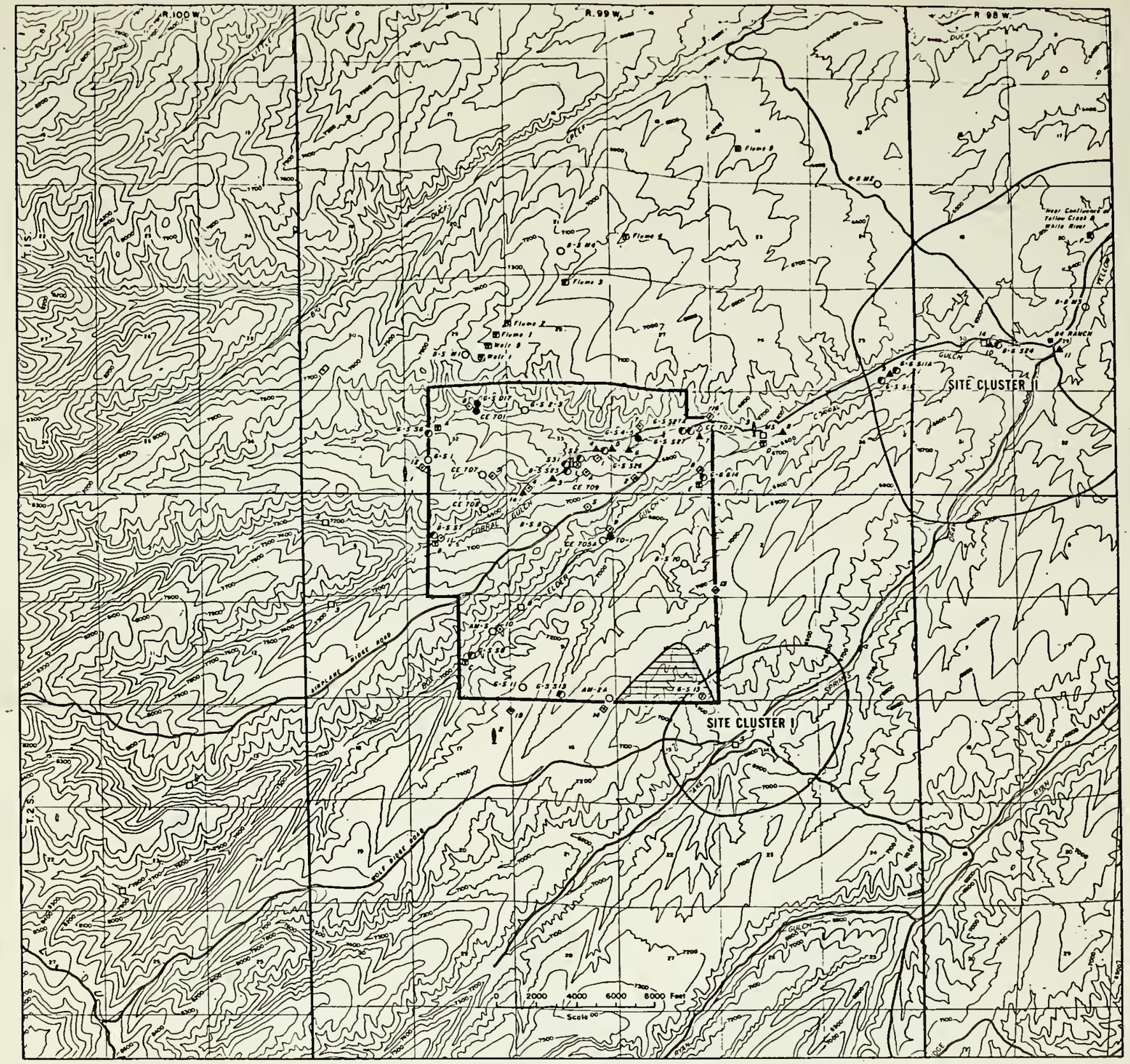
Ecological interactions are not measured or monitored directly. However, RBOSC's environmental monitoring program is providing data on a number of major ecosystem components. Assimilation and synthesis of these data have begun to confirm conceptual models and reveal certain (tentative) trends.

Deep, long-lasting snowcover during the winter of 1978-1979 may have influenced both the hydrologic and biologic systems. Increased spring runoff in 1979 relative to 1978 possibly resulted in a greater sediment load and increased erosion. The dilution factor associated with larger volumes of water may be related to a decrease in conductivity. Furthermore, increased erosion alters the stream substrate, as well as the aquatic biota which are dependent on this substrate.

The terrestrial ecosystem may also have been influenced by the long-lasting snowcover. Small mammals tend to be protected from cold temperatures and predation by deep snowcover and deer are forced to lower elevations for winter range, and/or may be restricted to south-facing slopes or ridgetops where snow accumulation is low. Increased moisture available during the early portion of the growing season can enhance forage production. However, if deer are concentrated in limited areas due to deep snowcover, browse utilization patterns may be altered.

Discharge of mine inflow seems to duplicate many of the processes and interactions which take place during normal periods of high runoff. In this instance, the activities on Tract C-a may be increasing the rate at which normal system interactions occur.

During the reporting period, human activity in the vicinity of Tract C-a has increased. In addition to oil shale development, there has been a noticeable influx of people related to natural gas exploration. The effects of development activities on wildlife are largely unknown. However, wildlife losses resulting from collisions with automobiles have increased slightly with increasing traffic. In spite of increased human presence, it appears that mule deer hunting may have declined during the fall of 1979.



Legend

- SPRING OR SEEP
- STREAM GAGE
- MONITORING WELL IN ALLUVIAL AQUIFER
- MONITORING WELL IN UPPER AQUIFER
- MONITORING WELL IN UPPER & LOWER AQUIFER
- MONITORING WELL IN LOWER AQUIFER
- EROSION - SEDIMENTATION SITE
- ENVIRONMENTAL SOUND MONITORING SITE
- MINE DEWATERING FLUME
- O.A. MUNSON PIPEYARD
- METEOROLOGICAL & AIR QUALITY MONITORING SITE
- PROTECTED HISTORIC REGISTER SITE
- SITE CLUSTER - AREA OF ARCHAEOLOGICAL SIGNIFICANCE

DATE	REVISIONS
6/7/79	[illegible]

Rio Blanco Oil Shale Company
RIO BLANCO COUNTY, COLORADO

ENVIRONMENTAL MONITORING SITES
MAP 1 - PHYSICAL

[illegible]	SCALE 1" = 2000'	FIGURE
[illegible]	DATE 6/7/79	E-199A
[illegible]		

R. 100 W.

R. 99 W.

R. 98 W.

T. 2 S.

SITE CLUSTER II

SITE CLUSTER I

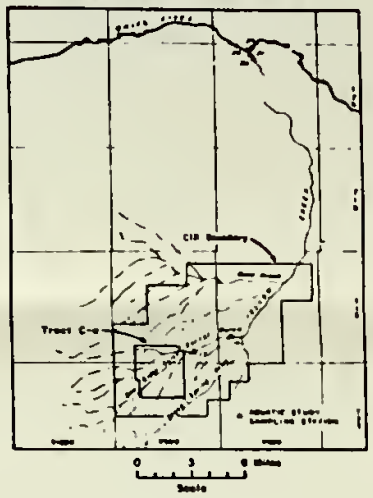
Inset Map 'A'

Inset Map 'B'

0 2000 4000 6000 8000 Feet

Scale

Regional Map Showing Aquatic Studies Sampling Stations



0 5 8 Miles

Scale

N

Legend

- 1979 COLOR INFRARED (CIR) PHOTOGRAPHY BOUNDARY - SEE REGIONAL MAP
- EXPERIMENTAL REVEGETION PLOT
- RANGE - BROWSE, PRODUCTIVITY & UTILIZATION STUDY SITE
- MULE DEER PELLET GROUP TRANSECT
- PHYTOSOCIOLOGICAL STUDY TRANSECT (PJ - PINYON/JUNIPER) - SEE INSET MAPS
- SHRUBLAND TRANSECT (PJ - PINYON/JUNIPER, S - SAGEBRUSH) - SEE INSET MAPS
- SMALL ANIMAL TRAPLINE (PJ - PINYON/JUNIPER, S - SAGEBRUSH) - SEE INSET MAPS
- B.A. WILKINSON PIPEYARD
- PROTECTED HISTORIC REGISTER SITE
- SITE CLUSTER - AREA OF ARCHAEOLOGICAL SIGNIFICANCE

0 1000 2000 Feet

Scale

DATE	DESIGNED
BY	DRAWN
	CHECKED
	APPROVED

The Rio Blanco Oil Shale Company

ENVIRONMENTAL MONITORING SITES

MAP 2 - ECOLOGICAL

9-1904.8

Form 1279–3
(June 1984)

BORROWE

TN 859 .C64 R56 De
Nov.79 v
Modular developmen
monitoring report

DATE LOANED	BORROWER

USDI – BLM